Corrosion

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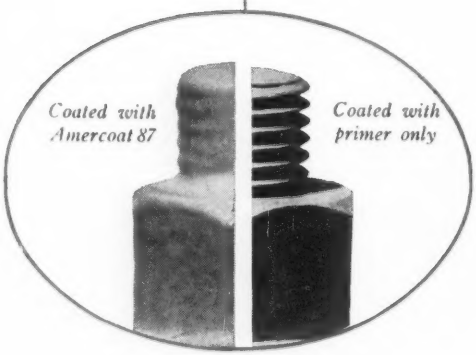
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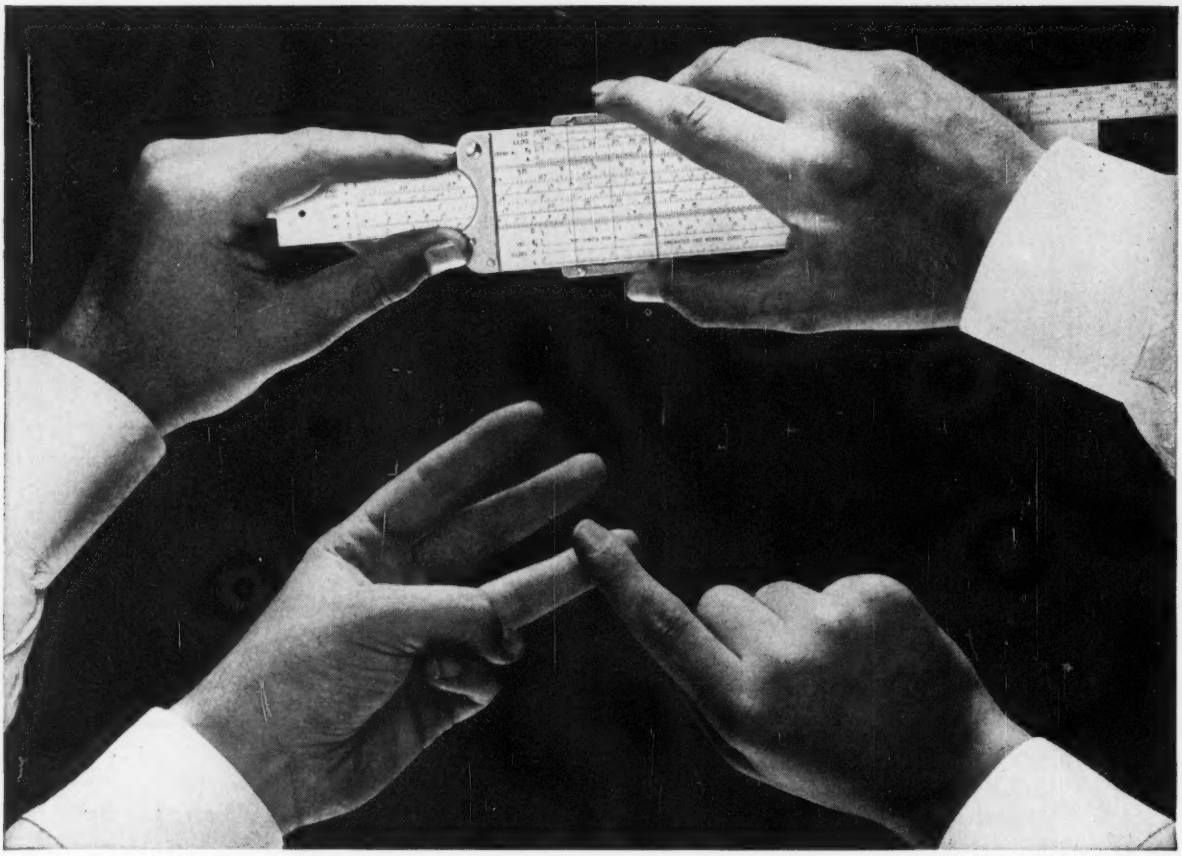
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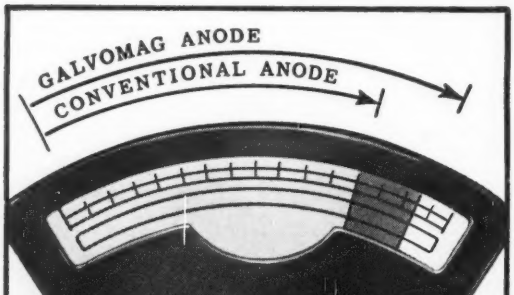
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devoted entirely to corrosion research and control

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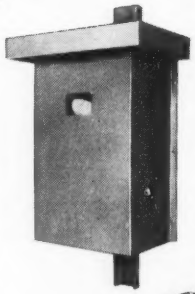
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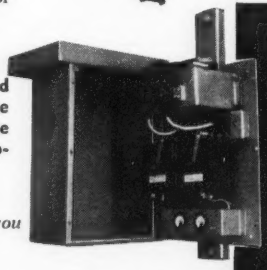
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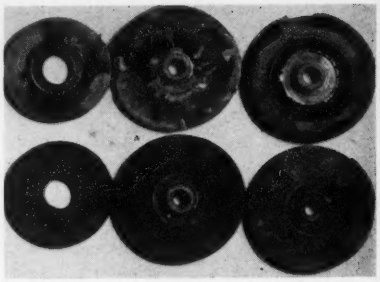


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THIS MONTH'S COVER—Test specimens shown here were subjected to 4112 hours' exposure in a hydrodesulfurization unit, including regeneration conditions. Flaky scale is typical of attack by hydrogen sulfide. This is the same as Figure 8 of NACE Technical Committee Report beginning on Page 47 this issue.

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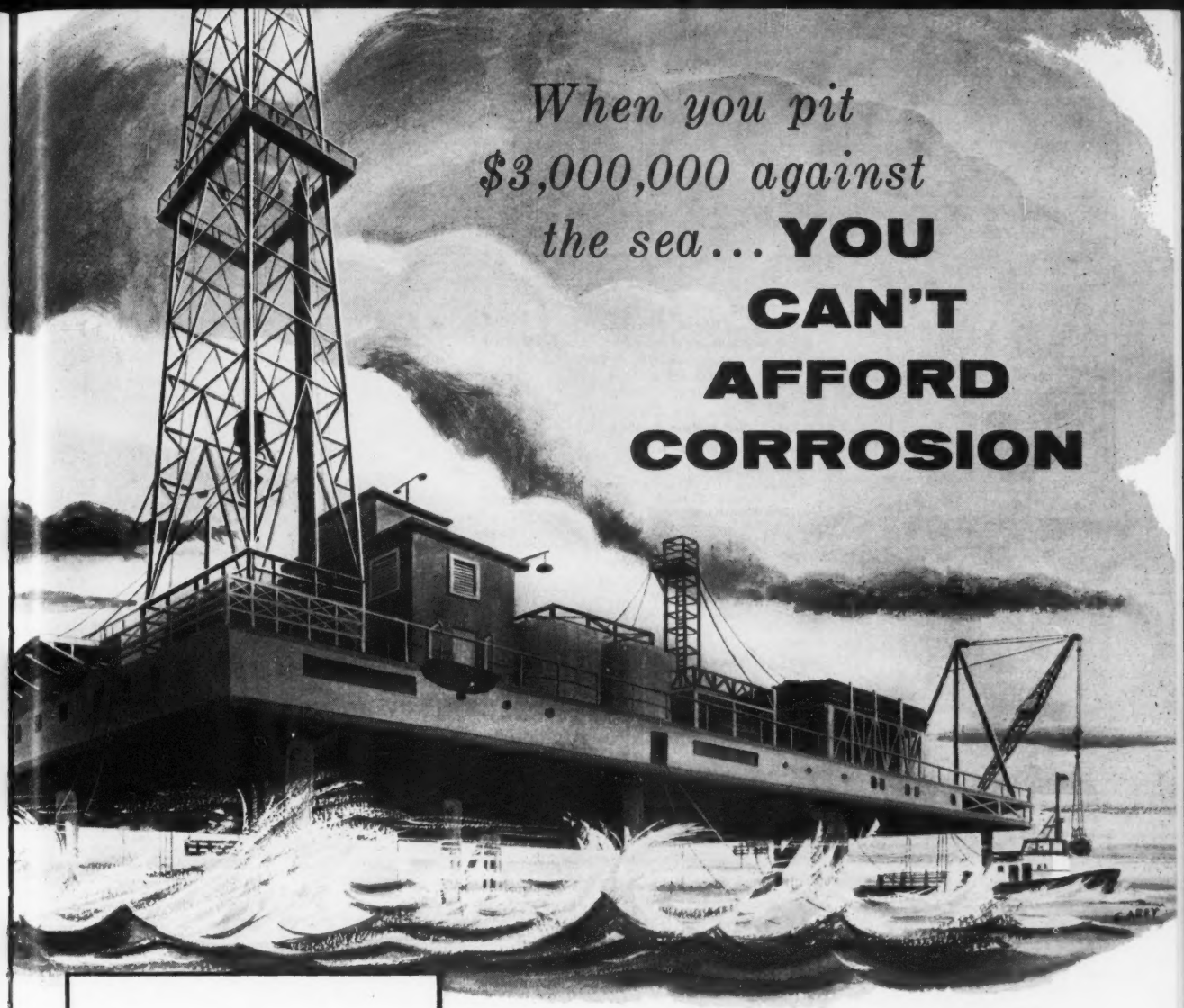
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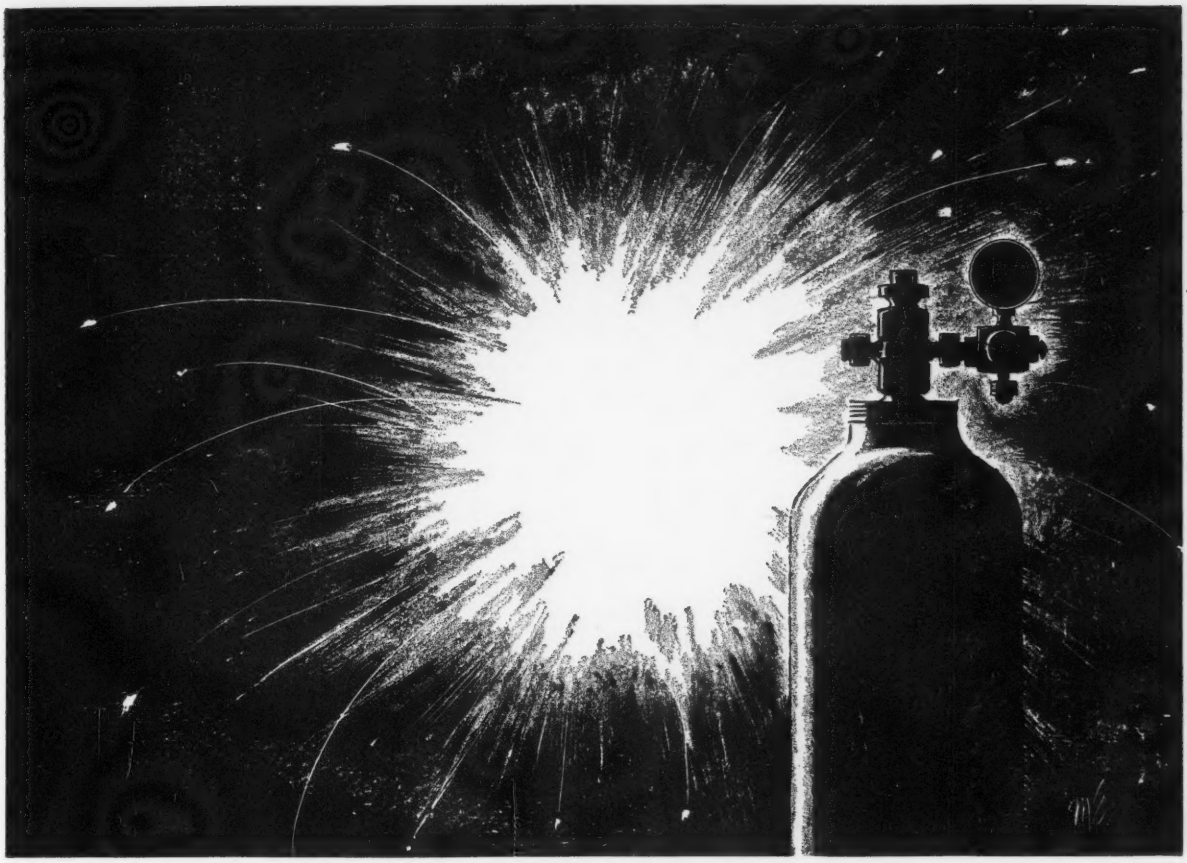
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(Continued on Page 8)



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Monel* nickel-copper and Inconel* nickel-chromium alloys, it has been found, resist attack by fluorine over a wider range of pressures and temperatures than other commonly used construction materials.

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At moderate temperatures . . . in aqueous systems . . . Monel is used

Up to about 900°F, Monel alloy shows good resistance to fluorine. It also resists liquid fluorine, hydrofluoric acid, anhydrous HF, HF-steam mixtures and active fluorides.

Currently, Monel alloy is widely used in nuclear fuel separation and HF alkylation processes . . · for fluorine generation cells, heat exchangers, scrubbers, process piping, control instruments and other equipment.

When temperatures go up... Inconel

Inconel alloy also provides high resistance to fluorine and other corrosives plus outstanding resistance to heat and thermal shock. A typical use is in the furnaces where anhydrous HF is reacted with uranium oxide to produce uranium tetrafluoride.

*Registered trademark

Pamphlets summarize new technology

Three helpful pamphlets, "Fluorine Corrosion," "Industrial Handling of Fluorine" and "Continuous Disposal of Fluorine," summarize recent developments in fluorine control. Write for copies. And for help in solving your specific corrosion problems, write to Inco's Development and Research Division.

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67 Wall Street New York 5, N. Y.

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(Continued From Page 6)

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• T-3G-2 Cathodic Protection of Heat Exchangers

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T-3H Tanker Corrosion

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• T-5C-1 Corrosion by Cooling Waters (South Central Region)

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John I. Richardson, Secretary, Amercoat Corporation, 4809 Firestone Blvd., Southgate, Calif.

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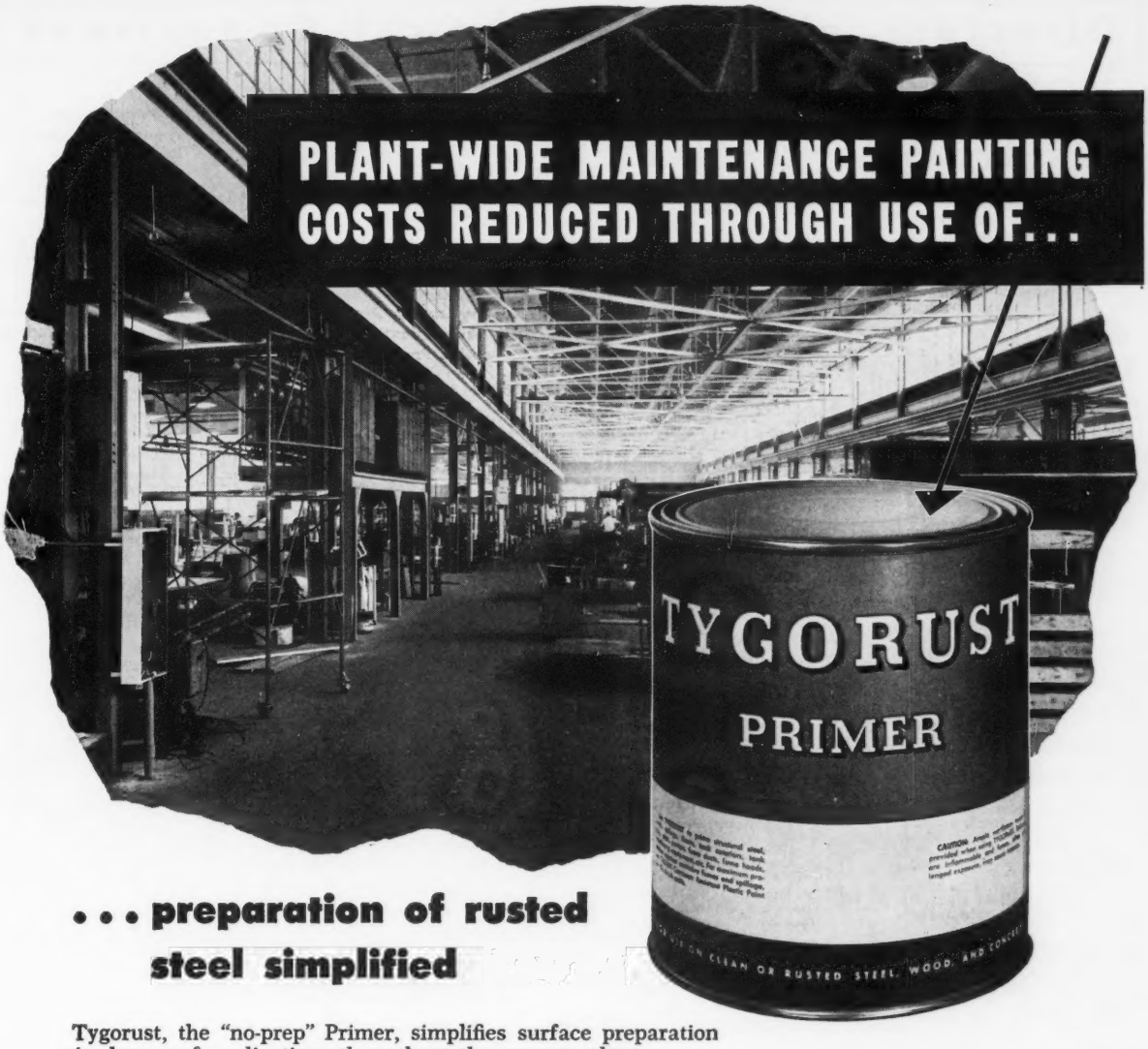
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• T-6A-9 Furanes

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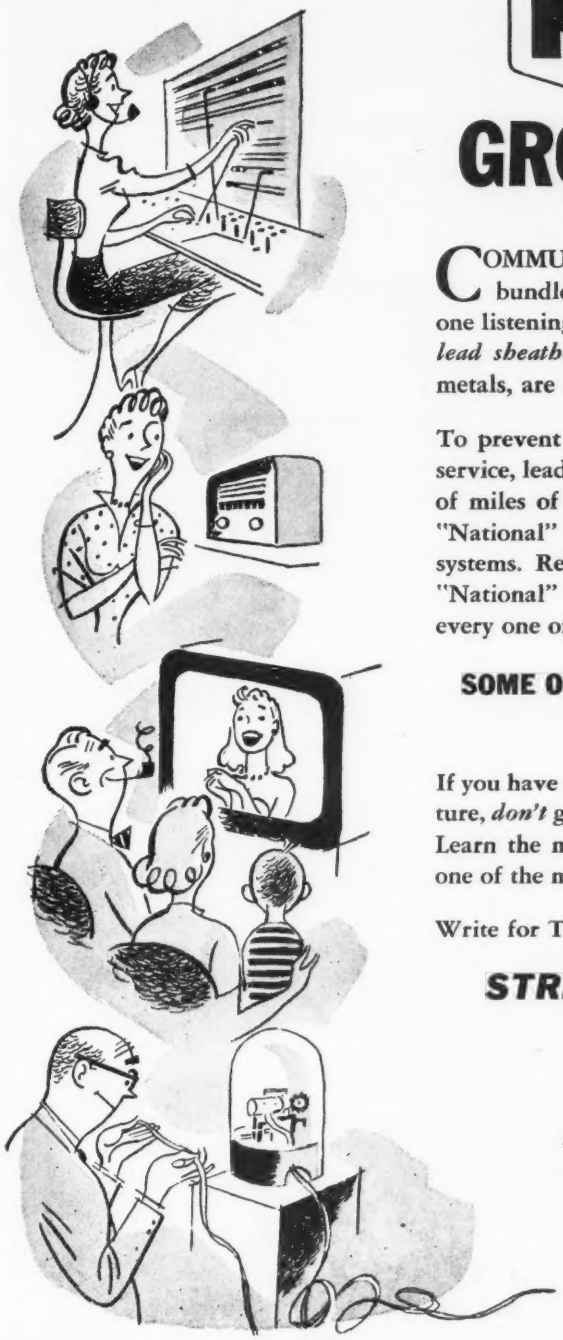
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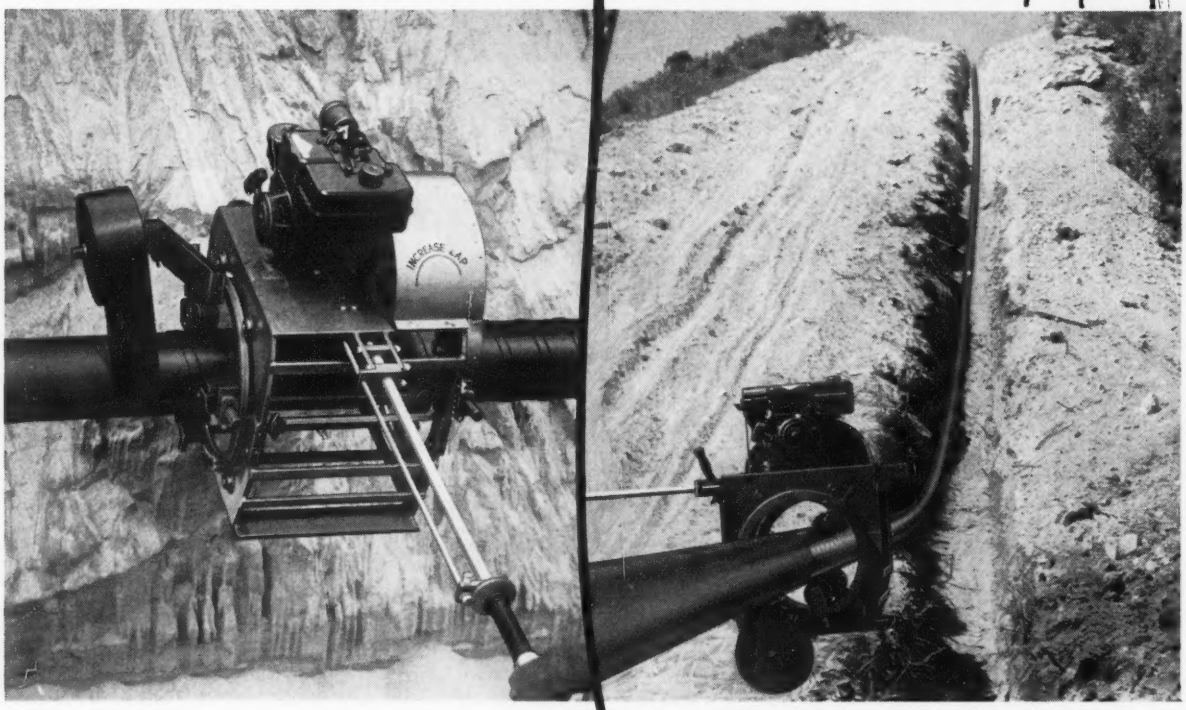
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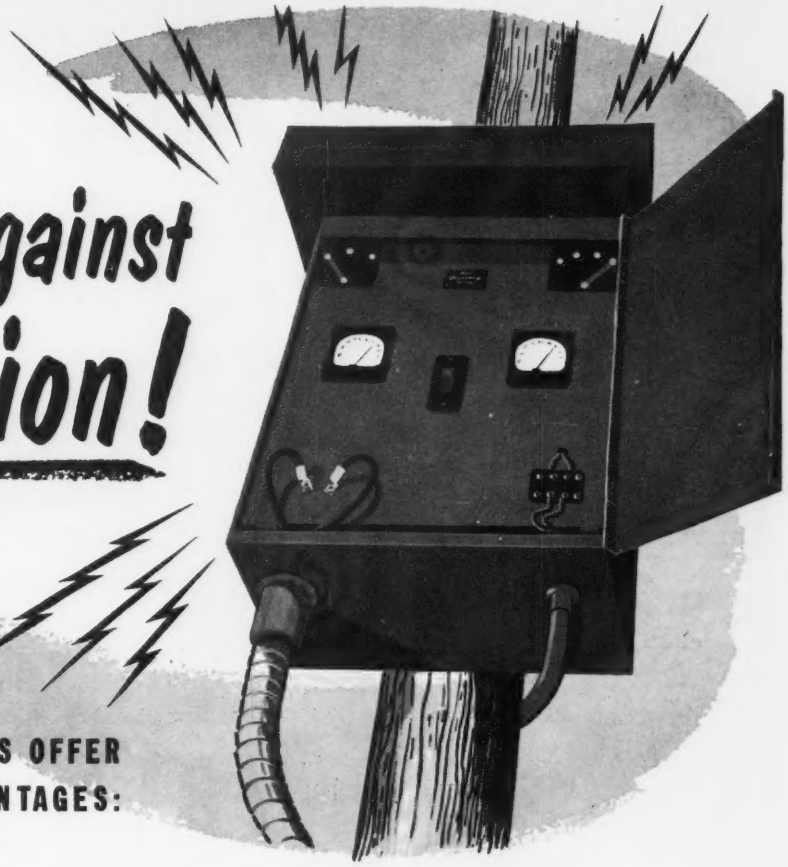
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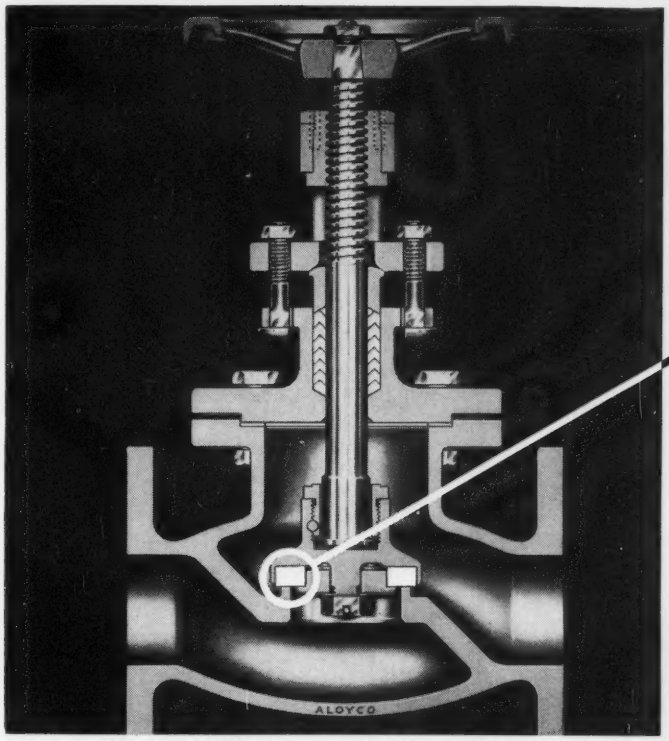
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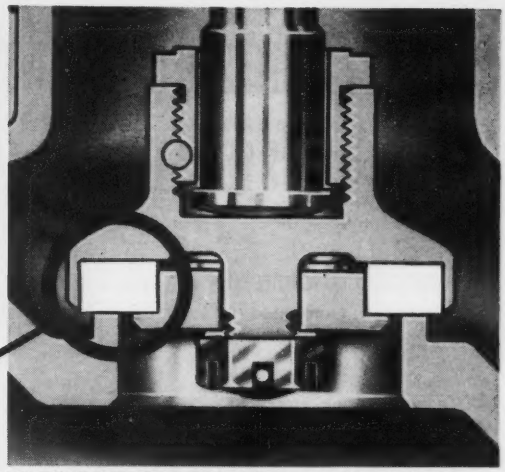
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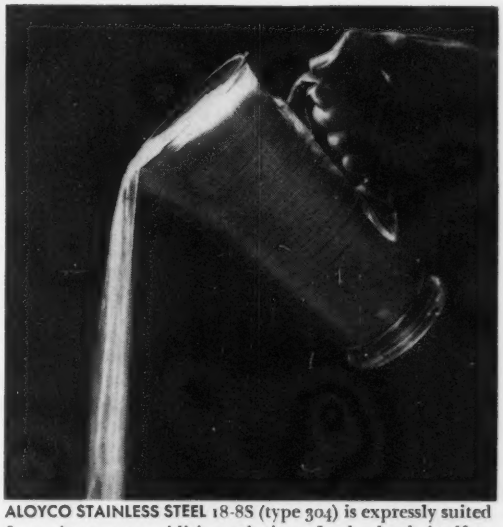
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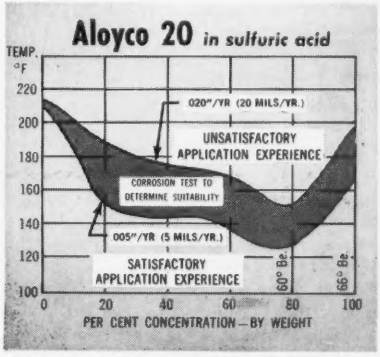
High chromium and chromium-nickel stainless steels are the best alloys for these corrosive applications.

When exposed to oxidizing solutions they form protective films which restrain corrosive attack. Aloyco 18-8S, 18-8S mo and Aloyco 20 are good examples.

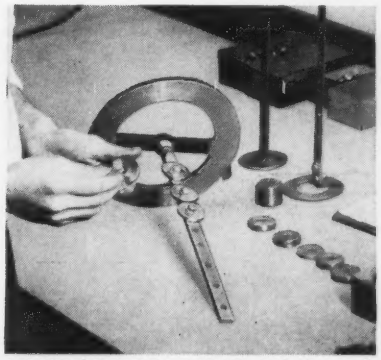
Valves should be constructed so that slight wear or corrosion won't require costly valve replacement. Renewable seats or discs shown above are one answer to this problem. So are deep stuffing boxes and outside screw and yoke construction. And, of course, all valve parts that come in contact with the corrosive fluid should be alloy steels. 6.18



ALOYCO STAINLESS STEEL 18-8S (type 304) is expressly suited for resistance to oxidizing solutions. It also lends itself to innumerable other applications to prevent product contamination or discoloration. In Aloyco 18-8S mo (type 316), molybdenum is added to increase resistance to attack by pitting.



ALOYCO 20 provides a high order of corrosion resistance to a wide range of sulfuric acid concentrations at varied temperatures as indicated by the graph above.



ALOYCO TECHNICAL SERVICE includes engineering counsel, metallurgical assistance and field service. Samples are being prepared for plant line test above.



FOR FURTHER INFORMATION on Aloyco corrosion-resistant valves, write to Alloy Steel Products Company, 1304 West Elizabeth Avenue, Linden, New Jersey.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are goverened by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

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Corrosion

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Topic of the Month

The Effect of Heat Treatment on the Susceptibility Of Sand Cast Aluminum Alloy 220 to Stress Corrosion Cracking

By FRED M. REINHART*

RECENTLY CONSIDERABLE difficulty was caused by failures of sand castings made of 220 aluminum alloy after relatively short service life in a marine atmosphere. The nominal chemical composition of this alloy is given in Table 1.

A casting which failed under the conditions described is shown in Figure 1. The cracks, in all cases, were approximately midway between the tops and bottoms of the castings. The radii of curvature of the castings and the mating surfaces of the structures were not identical which caused high tensile stresses to be imposed in the outer surfaces of the castings when they were drawn tight against the structures.

Examination under the microscope of polished and polished and etched sections showed that the cracks were intergranular and branching, typical of stress-corrosion cracks in aluminum alloys (see Figure 2).

As no information was available on the history of the heat treatment of these castings, specimens were machined from both failed and spare castings for laboratory tests to determine the effect of heat treatments on the susceptibility of this alloy to stress-

* Metallurgist, National Bureau of Standards, Washington, D. C.

TABLE 1—Chemical Composition of Alloy Used in Castings

Element	Percent by Weight
Cu	0.20 max
Si	.20 max
Fe	.25 max
Mn	.1 max
Zn	.1 max
Ti	.2 max
Mg	9.6-10.6
Al	Remainder

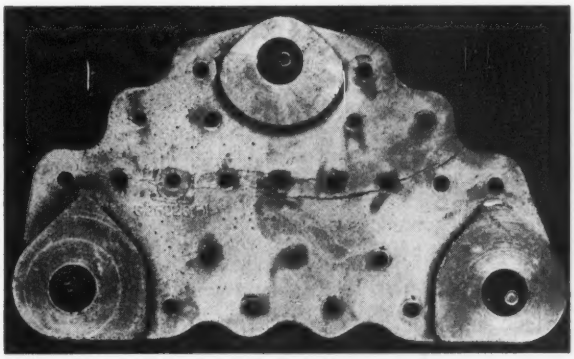


Figure 1—Stress corrosion cracks in failed 220 aluminum alloy sand casting. 1/6X.

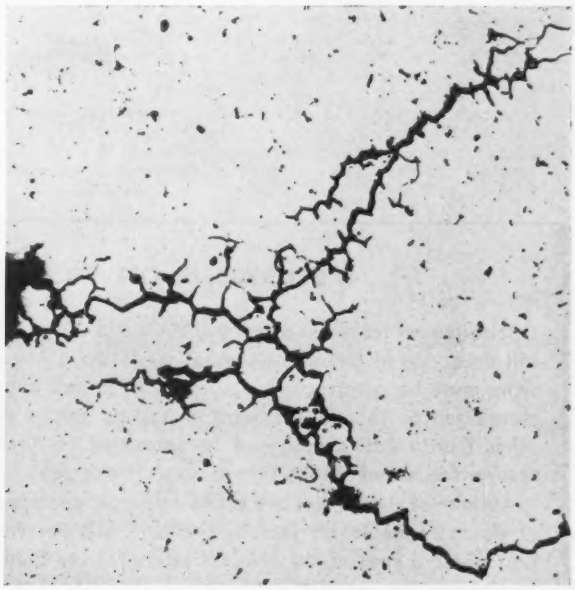


Figure 2—Intergranular, branching crack, typical of those found in failed castings. Unetched. 50X.

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corrosion cracking. The specimens were tested in the following conditions:

1. "As received."
2. Heated at 800-820 F for 18 hours; quenched in cold water; aged at room temperature for 96 hours, (Specification MIL-H-6088).
3. Heated at 800-820 F for 18 hours; quenched in boiling water and held there for 15 minutes; quenched in cold water; aged at room temperature for 96 hours.

The specimens were stressed in direct tension at loads equivalent to approximately 75 percent of the nominal yield strength of the alloy while being immersed in a corroding solution containing 57 grams of sodium chloride and 10 milliliters (30 percent) of hydrogen peroxide per liter. The specimens in the "as received" condition failed within one to eight hours, whereas the ones given heat treatments 2 and 3 were unbroken after 68 days.

These results show definitely that the susceptibility to stress corrosion cracking of this alloy is decreased appreciably when the rate of quenching from the solution heat treating temperature is increased. However, it is not always possible to quench parts at the rate necessary to render them immune to stress-corrosion cracking because of their size, danger of excessive warpage, or the production of high residual stresses. In such cases it is recommended that consideration be given to the substitution of alloys less susceptible to stress-corrosion cracking or to the use of forgings.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in Corrosion will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of Corrosion and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of Corrosion, 1061 M & M Bldg., Houston 2, Texas.

An Engineering Approach to The Estimating of Maintenance Painting*

By R. F. WILLIAMS and J. H. COGSHALL

Introduction

ESTIMATION OF the cost of industrial paint jobs is an operation for which there is little precedent in the literature and no recognized standards of procedure. For that reason it is not surprising that there are a number of widely differing approaches to the problem. This is particularly true for plants within the process industry, such as chemical manufacturing plants, in which paint protection serves the dual purpose of improving appearance and providing corrosion protection against severe spillage and fume conditions. As a result there is considerable variation in the estimates for any individual project from one estimator to another.

Estimated expenditures for future painting programs often are considered merely a rough approximation of the man-hours and money which a painting program might require. As a matter of fact gross actual discrepancies between these estimates and actual expenditures are the rule. Budget provisions based on such estimates are firmly fixed, and it is often found that toward the end of the painting season, scheduled and approved projects need to be severely curtailed or even eliminated to fit appropriations based upon these estimates.

The Problem

The Wyandotte Plant of the Pennsylvania Salt Manufacturing Company is one of the largest producing units within this company, and one which presents the greatest variety and severity of corrosive environment. It is basically a chlor-alkali plant, manufacturing also a variety of other related products. A great majority of the raw materials, intermediates, and products handled are either highly corrosive or deleterious to paint performance. This chemical plant is 50 years old, and hence, the variation in condition of the equipment and structures is wide, and construction details and materials varied. Up until a few years ago this plant conducted its painting on a job to job basis, with no advance planning or scheduling.

Within the past several years has come managerial and engineering realization of the high cost of protective painting within this plant. A determined program has been conducted to improve the efficiency of painting, and the durability of maintained appearance and corrosion protection of applied coatings. Some of the results of this continuing program in respect to material selection and preventive maintenance have been previously reported by Pierce[1,2] and Cogshall.[3]

In furtherance of this program, wasteful practices of job assignment were discovered. It was found that painting jobs had been authorized and approved on a job to job basis, the bulk of them on minor repair orders. Scrutiny of past sequences of painting authorizations disclosed that approximately half of such jobs were small jobs, averaging four man days or less. It is recognized that small paint jobs are most expensive, as the ratio of cost of getting prepared for the job and cleaning up after the job to the cost of surface preparation and paint application exceeds that of larger jobs.



RICHARD F. WILLIAMS was formerly shops supervisor of the Wyandotte, Michigan plant of the Pennsylvania Salt Manufacturing Company and is now with the Dow Chemical Company at Midland, Michigan. In 1943 he received a BS degree in mechanical engineering from New Mexico State College. He is a professional engineer (Michigan, 1950) and is a member of ASME and NSPE.



JAMES H. COGSHALL joined the Pennsylvania Salt Manufacturing Company as staff coatings engineer at its Wyandotte, Michigan works in 1950. Since August of 1953 he has been affiliated with the company's Corrosion Engineering Products Department in Philadelphia, Pa. Mr. Cogshall received a BS in chemical engineering from the University of Pennsylvania in 1938.

Abstract

Procedures which can be used to accurately estimate the cost of industrial maintenance painting are presented and discussed. The method involves the effect on painting costs of such variables as paint material, coating application, surface condition, pre-treatment, surface configuration, rigging, interference, environment, and posture required for painter. It has been found that estimators not having a broad knowledge of painting technologies are able to obtain reasonably accurate results with this method. It also has been found that this system will produce closely comparable cost predictions when used by different estimators. 1.2.2

* Submitted for publication January 12, 1956. A paper presented at the Twelfth Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 12-16, 1956.

The survey also disclosed that during the course of a single painting season one process may call in painters several times for local applications. It was discovered as a matter of fact that one process area was entirely repainted during the course of two successive painting seasons on a series of unrelated and costly Maintenance Request Orders. Such findings impressed the plant's Maintenance Engineering Department with the necessity of carefully screening all MRO requests in order to reduce their proportion, and combining related MROs into more productive large scale painting operations.

To effectively attain this objective of permitting painting labor to work with a minimum of diversion and interruption, it became imperative to anticipate and schedule painting requirements for six months in advance. In order that this future scheduling would be operative, it was also necessary to obtain in advance the required approval and appropriation for this entire projected painting program. Such approvals and appropriations could not be obtained without realistic estimates of anticipated costs. Such estimates must be realistic, as there is nothing so undermining of the confidence of management and operations as an unanticipated overrun request to complete an assignment.

The Considerations

Estimating of painting costs consists of two operations: calculating or estimating the square footage to be painted, and estimating the square footage cost of painting this area.

Calculation of paintable square footage is a reasonably straightforward matter. Linear circumference of various commonly used structural members and piping are calculated and recorded, and these multiplied by the aggregate length of such members in each size give accurate square footage.

Areas of tanks and process vessels may be calculated from common geometrical formulas or taken from tables with an additional calculation or percentage allowance for affixed nozzles and fittings. For the field of residential or architectural paintings there are certain established factors which may be given to allow for areas of window openings, doors, stairs, roof peaks, and other recurrent structural characteristics. It has been found that these factors are not usually applicable to equipment and structures which prevail within the process industries. Furthermore, it has been found that estimating square footage by aggregate tonnage of steel also is not reliable for the process industries, using currently published figures. There is sufficient standardization of design and equipment within the process industries to establish reliable factors for recurrent constructions used within the industry, but this is beyond the scope of the current paper.

Area calculations, once made for any process area or major item of equipment, are made a permanent record. Thus there is no need for a recalculation for future repainting operations, providing no alteration in the process or equipment has occurred in the ensuing period.

Over the course of the past three years attention has been given to studying the influence upon painting costs of various pertinent conditions. During this period four different methods of weighing these conditions were experimentally used in connection with Wyandotte painting programs. The outcome of this work is the Wyandotte method which is in current use in this plant. Its principles have been used and proven over the past three painting seasons, and by actual comparison of job estimates with actual cost of jobs, they have been found to be reliable within an average of 2 percent for any season's painting.

The Principles

This procedure consists simply of a quantitative rationalization of the effects upon total painting costs of the various conditions which tend to increase costs. Each of these conditions is discussed briefly below:

1. *Paint Material*

It is recognized that industrial painters are thoroughly experienced and familiar with application of oil-base, oleoresinous, or oil-derived paints. Faster drying synthetics and special coatings often required for chemical exposures require special techniques and precautions which must be observed in their application. In the use of these materials, costs of paint application increase.

2. *Application Procedure*

It is obvious that painting costs will increase with the number of coats specified in the painting system. In addition, the method of application of each coat has a bearing on costs. Of the application methods most common in industrial painting, it has been found that brushing is more expensive than spray application. Therefore, in estimating painting costs not only the number of coats to be applied, but the method of application must be considered. First coat applied, however, is always brushed to mechanically ensure adequate adhesion to the substrate. Some coatings do not lend themselves to spray application and it is found that roller applications in these cases compare favorably both cost-wise and time-wise with spray applicators.

3. *Surface Condition*

The initial condition of the surface to be painted profoundly affects costs of surface preparation. Surfaces with large areas of heavy, dense, adherent rust scale, or blistered, cracked and peeling paint, will entail much higher surface preparation costs than surfaces on which the previously applied paint film is continuous and intact, but possibly soiled. They also will show higher costs than bare steel surfaces covered with light, powdery and relatively nonadherent rust. In subsequent quantitative consideration of these effects on costs caused by variation in surface condition, no distinction is made among the various methods of surface preparation. It has been generally found, and assumed that for comparable finished quality of surface preparation, costs by one

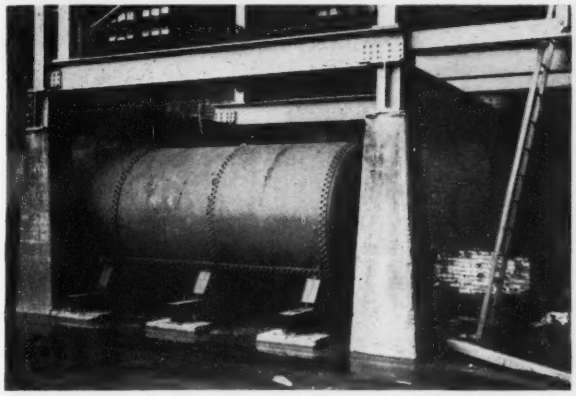


Figure 1—How complexity of surface configuration affects painting costs. Additive values for surface configurations are as follows: Tank = 0.50 (occasional projections such as bolts, nuts, lap welds, etc.); structural steel = 1.00 (heavy structural members). Other values are 0.50 for rigging additive and 0.60 for posture additive.

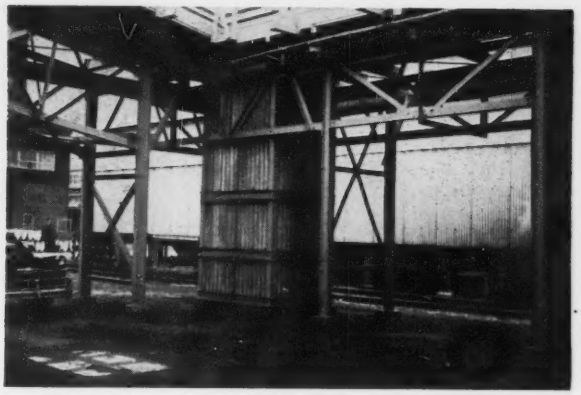


Figure 2—Additive value for surface configuration for this structural steel is 2.00. Rigging additive is 1.00.

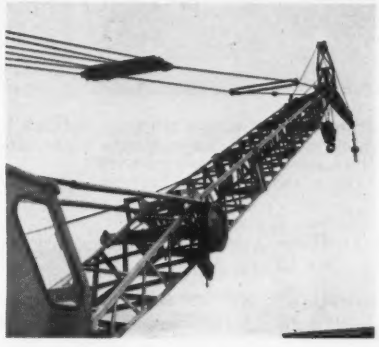


Figure 3—Additive value for surface configuration for structural steel pictured here is 3.00 (lattice, grating, etc. cause the value to be high).

method will be approximately comparable to costs by other methods.

4. *Pre-Treatment*

In many exposures within the process industries, pre-treatments after surface preparation and before priming are required for paint durability. Surfaces on which there is suspicion of moisture will be benefited by an alcohol wash. Surfaces with acidic contaminations in many cases will be benefited by neutralizing washes. In such treatments it will often suffice simply to wash surfaces, rinse, and dry to accomplish the desired results; in other instances, an actual scrubbing of the pre-treatment into the surface to penetrate and loosen soilage is required. Treatment and method of application will affect these costs.

5. *Surface Configurations*

It is axiomatic that costs of painting any unit surface will vary tremendously, depending upon whether that surface consists of an unbroken, continuous plane, or on the other extreme, of an interlaced complexity of light structural members. Therefore, the type of equipment or structure painted, especially as it deviates from the simplicity of a plane surface, must be considered in estimating.

6. *Rigging*

It must be recognized that the most rapid painting is performed when the workman is standing on solid footing with complete unrestricted freedom of movement. However, there are few industrial painting jobs where the complete operation can be done from the ground. When the workman is required to employ ladders, slings, staging, or rigging, his speed and continuity of application is necessarily reduced, thus increasing the costs of painting. This includes the cost of installing and removing the required staging and rigging equipment.

7. *Interference*

Rare is the painting job in an operating manufacturing plant in which the painters are allowed to proceed with their work to completion without interruption. Painting schedules necessarily are subordinate to operations; in many instances painters must wait for completion of required preliminary operations by other maintenance crafts. Such interruptions are wasteful of painter man-hours and must be considered in costs. Inclement weather also affects continuity of painting operations.

8. *Environment*

Within any painting operation, and especially those within the chemical industry, workmen may be required to conduct their operations within areas of unpleasant fume or temperature conditions. The use of masks or protective clothing hampers the speedy conclusion of operations, and temporary installation of relieving exhaust fans or blowers adds to the cost of the maintenance operation.

9. *Posture*

It is recognized that any workman will work most efficiently when he can always maintain a comfortable position with unrestricted movement. If working conditions require him to work in a cramped or



Figure 4—Additive value for surface conditions for structure pictured is 0.00. This is because the loose surface dirt can be easily removed by wirebrushing.

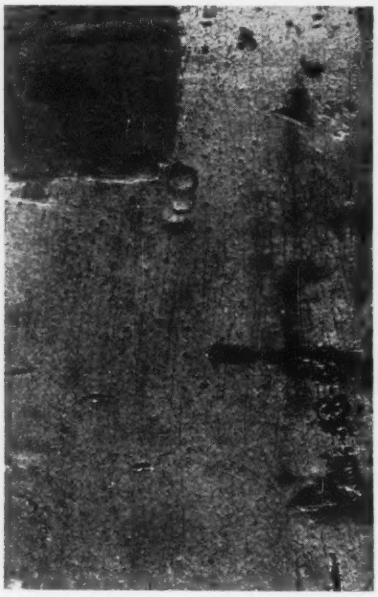


Figure 5—Additive value for surface condition here is 0.30. In this case there is light pin point or powdery rust.

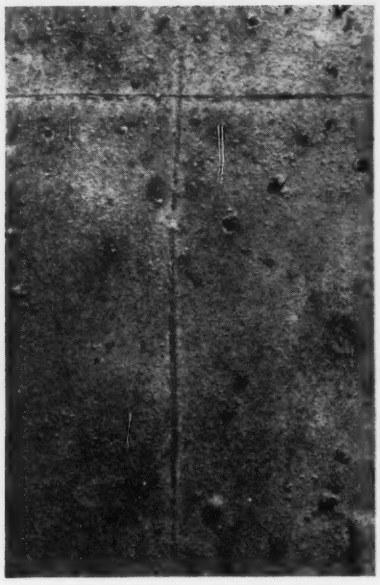


Figure 6—Additive value for surface condition of metal shown is 0.60. Note occasional blisters and rust patches.

unnatural position, speed of operation will be sacrificed, if quality is maintained.

All of the above factors which influence painting costs are well known and recognized. The only contribution made in presenting them here is to provide a check list to ensure during estimation that no pertinent factor is overlooked. Under painting conditions as they exist at the Wyandotte plant it has been determined that these nine factors are sufficient to properly estimate painting costs. It is appreciated that in other plants with somewhat different conditions, certain of the factors considered here might conceivably be of less importance, and that other factors not included should be added to the list.

The Method

For estimating purposes, it is necessary to first establish an average base of painter man-hour productivity. This base productivity was arbitrarily established as the rate at which an average and typical painter within the Wyandotte paint crew would complete a "basic" 100 sq ft of surface. This "basic" surface was defined as a continuous vertical area of plane surface which was (1) All at painters trunk height, (2) In the open thus allowing unrestricted painter movement and, (3) Of such surface condition that only minimum hand brushing would be required prior to paint application.

The "basic" application was designated as a one coat brush application of an oil-base, oleoresinous, or oil-derived coating applied under ideal weather and other conditions for paint application. Four years ago, at the outset of this study, this base productivity rate was established from observation and interpolation of actual completed paint jobs to average six man-hours per hundred square feet. In the following three years this base productivity average has fallen from six to four man-hours. This gradual decrease in labor consumption is attributable in large part to increasing efficiencies developed by the paint crew as a result of the practice and the instruction of the educational program which accompanied the Wyandotte maintenance painting evaluation and standardization program. Other factors are (1) The increasing familiarity by the workmen of the new special materials which they are sometimes required to apply and (2) The adjustments in the base productivity rate found to be necessary to adjust the estimated costs to actual costs.

It is recognized that even the current productivity of four man-hours per hundred square feet is high. Even when taking into consideration the fact that the turnover in the paint crew is no less than normal for chemical industrial painting, and that it is necessary that sufficient time be taken in application to ensure quality, highly durable performances, it is clear that this productivity rate can be still further reduced. Reduction of this rate, without sacrifice of quality of application and durability of applied coatings is a subject of separate study.

Having thus established this base productivity it is now necessary to determine the adjustments required for deviations from this ideal base application. To do this a multiplying job factor is determined. When this job factor is multiplied by the base productivity, the anticipated labor usage for any individual paint application will result. Obviously if a paint job is contemplated which is equivalent in all respects to those conditions established for the base application, the job factor will be 1.00 and the anticipated labor expenditure for the job will be



Figure 7—Additive value for surface condition here is 1.00. Value is higher than in Figure 6 because of the presence of moderate blisters and rust.



Figure 8—Additive value for surface condition in this case is 1.50. Here severe blisters and rust are present.



Figure 9—Additive value for surface condition shown is 2.00. In this case severe blisters and scale are noticeable.

at the rate of four man-hours per 100 square feet. If, as is more usually the case, conditions more adverse than those established for the base rate are encountered, the job factor of 1.00 must be increased to compensate for the added difficulty of application imposed by the specific conditions. Some typical surfaces are shown in Figures 1-13. By actual labor rate measurements, and by a process of continual factor adjustment to bring estimated costs in line with actual costs, the following schedule of increases due to variations in adverse conditions was obtained:

Base Painter Productivity . . . . 4 Man-Hours/100 Sq Ft
Based on:

1. Application of one brush coat of oleoresinous paint.
2. Minimum surface preparation.
3. No wash or rinse.
4. Application to continuous vertical plane surface at painters' trunk level.
5. No scaffolds, ladders or rigging required.
6. No abnormal interruptions during application.
7. Painters standing on ground with unrestricted movement.

Basic Job Factor 1.00

Increase this job factor by the following additives for each operational condition:

1. Paint Material
   0.00 Oleoresinous, alkyds, phenolics.
   0.10 Chlorinated hydrocarbon resin.
   0.30 Chlorinated rubber, vinyls.
   0.60 Maintenance neoprenes, epoxys, paints requiring accelerator addition.

2. Application (basic additives: 0.20-Spray; 0.30-Roller; 0.40-Brush)
   0.00 One coat, brush.
   0.20 Two coats—one each by brush and spray.
   0.40 Two coats brushed, or three coats of which one is brushed and two sprayed.
   0.60 Four coats, three of which are sprayed.
   0.80 Three coats brushed, or five coats of which one is brushed and four sprayed.
   1.20 Four coats brushed.
   1.60 Five coats brushed.

3. Surface Condition (see Figures 4-13)
   0.00 Loose surface dirt, easily removed by wirebrushing.
   0.30 Light pin point or powdery rust.
   0.60 Occasional blisters or rust patches.
   1.00 Moderate blisters and rust.
   1.50 Severe blisters and rust.
   2.00 Severe blisters plus scale.
   2.50 Heavy scale.

4. Pretreatment
   0.00 No wash.
   0.20 Light rinse or neutralizing.
   0.40 Scrubbing.
   Add 0.20 for each wash between coats.

5. Surface Configuration (see Figures 1, 2, 3, 11, 12 and 13)
   0.00 Plane surface.
   0.50 Occasional projections, such as bolts, rivets, lap welds, etc.
   1.00 Heavy structural members.
   2.00 Light structural members.
   3.00 Lattice, grating, etc.



Figure 10—Additive value for surface condition pictured is 2.50. Value is high because of the presence of heavy scale.

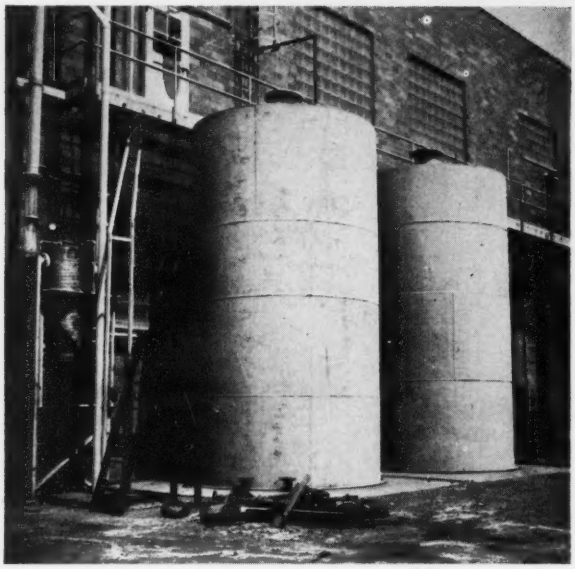


Figure 11—Surfaces shown here all require wirebrushing with scrapers being needed in some areas. Additive value for surface condition here will average 0.10. Because objects to be painted have very nearly plane surfaces the additive value for surface configuration is 0.20. Some allowance is made for welds and flanged openings.

6. Rigging
   - 0.00 No rigging.
   - 0.50 Ground and ladders.
   - 1.00 Ladders only.
   - 1.50 Swing stage and ladders.
   - 2.00 Scaffolding or other complicated rigging.

7. Interference
   - 0.00 No interference.
   - 0.10 Remote from shop; outside job.
   - 0.20 Slight interference (remoteness plus outside job).
   - 0.40 Moderate interference (requires coordination with production).
   - 0.60 Heavy interference and interruption.

8. Environment
   - 0.00 Comfortable conditions.
   - 0.20 Gas influence (applied when working in known offending areas).
   - 0.30 Moderate temperature or humidity influence.
   - 0.40 Severe temperature or humidity influence.

9. Posture
   - 0.00 Standing on firm footing, painting at trunk height.
   - 0.30 Stooping, kneeling, sitting.
   - 0.60 Crawling and reaching.
   - 0.90 Lying, crawling, reaching.

Application of Method to a Specific Case

As an example of the use of this method, consider the case of a horizontal steel riveted acid storage tank 10 feet in diameter and 40 feet long. Such an tank is pictured in Figure 14.

The influence of each of the nine factors for a prospective paint application to this equipment are given in the following paragraphs, and the quantitative additives estimated:

Additive

1. *Paint Material*

It was proposed to paint the tank shown in Figure 14 with a three coat chlorinated hydrocarbon system. As will be noted from the additive schedule this system calls for an additive of 0.10. **0.10**

2. *Coating Application*

It is proposed to apply a three coat chlorinated hydrocarbon system of which the prime coat is brushed. Reference to the application schedule shows this carries an additive of 0.40. **0.40**

3. *Surface Condition*

In consideration of this additive, two types of surface conditions are involved. The tank proper is of well weathered steel, with mill scale absent and light rust overall with little or no pitting. The structural supports and platform, however, are of new steel and have mill scale which must be removed by sandblasting.

Wherever instances of dissimilar conditions exist, two alternates are available: Separate estimates may be run for the areas of each condition, or the composite effect may be mentally averaged to apply to the job as a whole. The latter is recommended, inasmuch as dissimilarities in conditions may exist in each of the nine categories resulting in a cumbersome extent of subdivisions, if the first recourse were used.

The new structural fabrication would take an additive of 2.00, and the tank body itself no additive. Averaging out these additives for the job as a whole, taking into account proportional areas, gives an average additive of 0.40. **0.40**

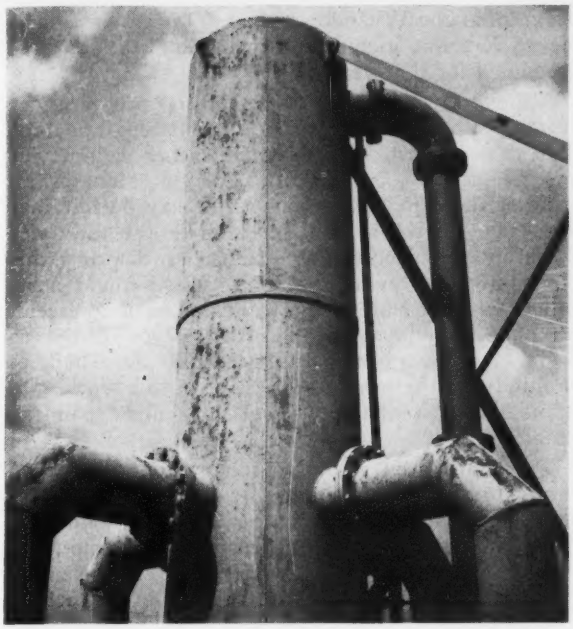


Figure 12—Additive value for surface conditions here is 0.60 because of the presence of blisters and rust patches. Distribution for surface configurations averages 0.80 because of the distribution between planes, projections and heavy members.

4. *Pre-Treatment*

No metal pre-treatment is contemplated for this job. 0.00

5. *Surface Configuration*

Once again, there is a composite situation to be mentally averaged. The tank proper falls into an interpolated additive classification of about 0.50 whereas the platform and supports are of light structural steel construction and grating, with an additive for these of approximately 1.5. An average, considering proportionate areas, would be in the order of 0.80. 0.80

6. *Rigging*

Much of the painting can be carried on from the ground, and with the addition of ladder work all operations can be performed; thus, the table gives an additive for this situation of 0.50. 0.50

7. *Interference*

No interference in the progress of this work is contemplated. But because the job is an outside one and is located about one-fourth of a mile from the paint shop and source of supplies and equipment, an additive of 0.20 is assigned for this greater than average remoteness. 0.20

8. *Environment*

Working conditions are expected to be favorable, and as the job is scheduled for the early fall of the year no adverse weather conditions are anticipated. For this reason no additive is assigned. 0.00

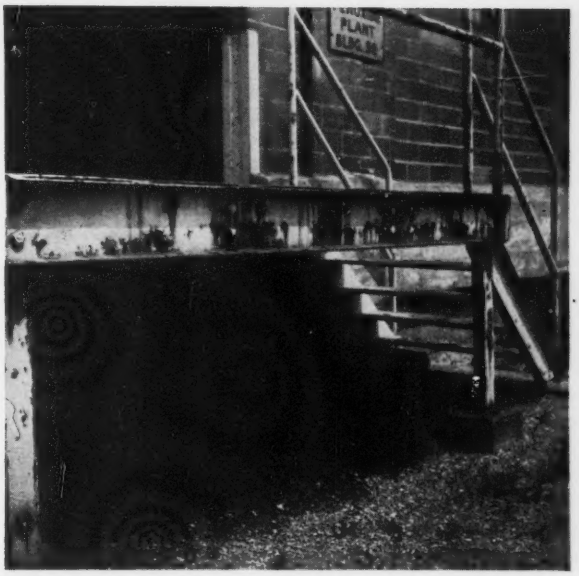


Figure 13—Additive value for surface conditions here is 1.00 because of moderate blisters and rust. There is a balance of light and heavy structural members which causes the additive for surface configurations to average 2.00. Additive for posture will be 0.30 (stooping, kneeling and sitting all are required for painting).

TABLE 1—Correlation Between Actual and Estimated Costs for 1954 Painting Program

Job	Area In Square Feet	Job Factor	Man-Hours		Job Deviation
			Estimate	Actual	
54- 1	1006	6.1	307	345	+12%
54- 2	3850	4.7	905	719	—10%
54- 3	1217	4.2	256	314	+23%
54- 4	1822	2.8	255	106	—58%
54- 5	754	2.7	102	132	+30%
54- 6	2615	3.5	329	385	+17%
54- 7	454	4.5	101	70	—30%
54- 8	819	3.3	135	100	—26%
54- 9	328	2.7	45	88	+95%
54-10	743	3.4	129	104	—19%
54-11	280	4.7	74	94	+27%
54-12	1320	3.2	158	118	—25%
54-13	2530	4.8	582	629	+ 8%
54-14	1713	4.7	399	376	— 6%
54-15	628	2.7	87	165	+90%
54-16	708	3.95	140	172	+23%
54-17*					
54-18	1919	4.1	393	418	+ 6%
54-19	4200	3.8	798	547	—30%
54-20	1726	4.0	345	455	+32%
54-21	2321	4.2	488	517	+ 6%
54-22	1578	6.4	494	663	+34%
	32531		6522	6517	

Program deviation-(5/6522) x 100 = —0.077%
* Originally scheduled but later cancelled.

9. *Posture*

It will be noted that considerable, but not all painting must be conducted in a crawling, stooping, and reaching position. This is especially true when working under the tank, around the tank supports, and under and around the platform. For these reasons a proportional additive of 0.50 has been assigned. 0.50

Total of Additives 2.90

This aggregate additive of 2.90 when added to the base job factor of 1.00 gives a job factor of 3.90 by



Figure 14—Storage tank used in estimate of maintenance painting.

which the base productivity must be multiplied to give an estimate of the man-hours which must be allowed for doing the job. Here four man-hours times 3.90 equals 15.6 man-hours per hundred square feet of painted area. Thus, it may be seen that this job is approximately four times as difficult to do, as measured by labor requirements, as the same area would be with a continuous plane surface under ideal application conditions at trunk height from a painter working from free ground.

The paintable area having been previously recorded, the total man-hours for this job can be calculated and scheduled. By applying to this figure the standard wage rate per painter, the labor cost for the job can be estimated. Knowing this square footage, the factual coverage of the materials used, and their cost, the amount and cost of material can be estimated.

It should be noted that while assignment of values for the various additives are subject to considerable variation in personal judgment, a wide error in any one such assignment will have relatively little effect on the finished estimate. For the above example, the rigging additive was adjudged to be 0.50. If 1.00, a 100 percent deviation, represents more truly the actual rigging conditions, the estimate using the 0.50 figure will be in error only by 12.8 percent. By any other method of estimating a 100 percent error in judgment would result in a 100 percent error in the final estimate. Actually small personal deviation in judgment in evaluating each of the additives for the nine different conditions will, according to the law of averages, tend to offset one another.

Results

As the proof of any pudding is in the eating, the effectiveness of any proposed system is in the results. In Table 1 estimated painting costs may be compared with the actual costs of doing the twenty-two scheduled paint applications within the 1954 paint program at the Wyandotte plant. This is not a hand picked list, but includes all paint applications prescheduled for that year.

TABLE 2—Accuracy of Estimates

Estimates Accurate Within:	Percentage of Job Estimates Made	Percentage of Area Painted
10 Percent	24	37
20 Percent	38	51
30 Percent	76	82

NOTE: As shown in bottom line, 76 percent of job estimates are accurate within 30 percent. This means that only the remaining 24 percent of estimates have errors in excess of 30 percent. The percentage of area involved for estimates having errors in excess of 30 percent would be 100-82 (or 18 percent.)

Although estimates for the entire program accurately predict costs, it is immediately apparent that, in some instances, there are rather wide deviation of specific job costs from the job estimates. In view of these job discrepancies, it may be felt that agreement of the season's costs with the estimates is purely coincidental. As evidence to disprove this conjecture, a previous season's record found costs in line with estimates within a deviation of 2 percent, although individual job discrepancies varied as widely as shown in this 1954 record. It must be kept in mind that the primary objective of this work is to realistically predict costs for an entire painting season.

There are very sound reasons why this method in its present form cannot be dependably used to make individual job estimates. It was designed to make estimates for an entire painting program, and as such accomplishes this objective. There is no question that adjustments can be made in the method which would bring individual job estimates closer in line. It is felt, however, that the added considerations needed to accomplish this are not justified, as current objectives are adequately satisfied by this simpler approach.

Job Deviations

The year's program was examined to determine the type of job for which the greatest deviation occurred. The significant results of this examination are tabulated in Table 2. It may be seen from this table that 24 percent of all of the estimates made, representing only 18 percent of the area painted that season, showed deviations from the estimate of more than 30 percent. These necessarily then must be smaller jobs. That these smaller jobs deviate most greatly from estimates is further verification of the established convictions that small jobs, wherever possible, should be avoided or combined as larger undertakings. It is further confirmation of the poor economy in doing any but the most necessary painting under minor repair orders.

The most apparent reason for this departure of small jobs from reasonable estimates is the disproportionate labor time required in setting up to do the job and cleaning up after the job, to actual surface preparation and application time. Certain job histories are known where these non-productive labor diversions actually exceeded the labor time required for surface preparation and paint application.

One of the greatest causes of deviation from estimates is found to be non-uniformity of workmen. A typical paint crew, by painting knowledge and ability, is divided into three or more craft classifications according to skill, and varies even more widely than this in efficiency and workmanship. It will be noted that neither the base productivity rate nor the additive adjustments take into consideration varying qualities of workman efficiency. Conceivably this could be done, but it is felt that this would introduce such complexities in estimating, that the trouble

would be more than the worth. This factor, of course, is contributary to the greater deviations in estimating the smaller jobs.

On any job which requires the entire paint crew, differences in workmanship from man to man would average out to the base productivity rate used. On a small job requiring but relatively few workmen the actual base productivity, depending upon ability of the assigned men, may vary from three man-hours to six man-hours. This causes deviations of this proportion in a final estimate, which is based upon an average productivity of four man-hours.

During the course of an entire season's painting, workmen of varying efficiencies will be occupied during the entire season and the season's cost will average out to the average productivity figure used. That this is the case is amply demonstrated by the 1954 painting record, where estimates for the season's painting, based upon an average basic productivity, equals exactly the actual season's costs. This occurs in spite of rather appreciable deviations on several individual jobs.

Where it is desirable to more accurately estimate costs of individual jobs, additional environmental additive classifications might be included. These should in one instance be related to job size, with paintable area as the index. The quality of workmanship of the various men assigned to the job should be another, the index in this latter case being less apparent.

This Wyandotte method of estimation is currently established and presented for use only with complete overall painting jobs. Its principles, with adjustment, are equally applicable to spot repair operations, although the adjustments required to adapt it to this type of work have not been fully worked out as yet.

Summary

A method and procedure for estimating the cost of an industrial maintenance painting program is presented and discussed. This method has proven by actual experience to give accurate results when used by estimators without intimate knowledge of painting technologies. It also has proven to provide consistent estimates, made by various estimators using its principles.

In its present form this estimating method has given realistic results in estimating the cost of projected paint programs over the past three years. In its present form it is not strictly dependable in estimating costs of individual small jobs, or spot-repair operations. Logical adjustments may be made to the method, however, to make it reliable for such assignments.

In its operation it separately considers the various factors which affect painting costs. Therefore, its use infallibly discloses such conditions which adversely affect plant paint maintenance costs, such as low painter productivity, poor design, advanced coating, deterioration, among others. By this feature it indicates most profitable avenues for further reduction of plant maintenance painting costs.

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Any discussion of this article not published above will appear in the June, 1957 issue.

Analysis of Corrosion Conditions Using Cable Sheath Current Measurements*

By J. M. FOUTS[1] and C. W. BERGERSON[2]

Abstract

The technique of current loss analysis using structure to earth potential measurements is wholly inadequate for use with large cable networks in multiple conduit systems. Duct surveys also have limited application.

A newly developed method of making large numbers of sheath current measurements is described. This system is known as the "Zero Resistance Ammeter Method." When it is employed the potential drop over the test section of cable sheath is observed with a galvanometer which is used to determine the direction of current flow and as a null indicator. In making the measurement a direct current potential of opposite polarity to the potential appearing across two points is applied across two other points under control of resistance and adjusted until the galvanometer indicates a null. At this condition of balance there is no potential drop across the first two points. The current indicated by the ammeter is the current required to produce the zero potential drop and therefore is equal to the current that flowed in the test section between the first two points.

The application of current measurement data to corrosion analysis is discussed in detail. A sheath current diagram for four manholes is one of several illustrations included.

Consideration is given to electrical problems involved in the measurement of small currents in very low resistance circuits. Electrical characteristics of test circuits are discussed in detail. An equipment arrangement is described with sufficient simplicity and accuracy to permit the average field tester to obtain measurements suitable for analysis of current loss or pickup. 4.5.3

Introduction

THE FUNDAMENTAL problem of the corrosion engineer responsible for the prevention of corrosion of an underground structure is that of determining the area and the severity of exposure. For the purpose of this discussion, exposure will be defined as that portion of the structure from which current is flowing to the surrounding environment. Because the corrosion rate is proportional to the magnitude of the current leaving the structure, the engineer is vitally concerned with the accurate determination of the magnitude of this current loss.

Testing techniques have been developed that do a reasonably adequate job of obtaining this information in the case of long single structures, such as pipes and cables buried directly in the earth in open country. These structures permit electrical connection at almost any point, while direct contact with the earth can generally be made directly over or near the structure. Under these conditions, structure to earth potential measurements can be made according to the requirements of the various analysis techniques and a reasonably adequate determination made of the area and severity of current loss.

In the case of large cable networks in multiple conduit systems, such as exist in the urban sections of cities, the technique of current loss analysis using structure to earth potential measurements is wholly inadequate and in many cases may lead to erroneous conclusions. Many factors contribute to this condition. The more important may be summarized as follows:

1. There are a number of inherent physical limitations due to the type of construction. In many cases sidewalk and street paving cover the entire area from building to building for long distances over the conduit run, making direct contact with the earth impossible.

2. Access to the cable network for electrical connection is limited to the manholes, which vary in spacing from a few feet to about 750 feet. The average spacing is about 500 feet, except where short blocks are encountered in downtown areas.

3. The close proximity of a maze of other underground structures that exist in all urban areas creates a complicated electrical network that affects the distribution of any current that may be flowing in the earth.

Cable to earth potential measurements made to the floor of the manhole are in general neither adequate nor entirely reliable data on which to base an analysis of corrosion conditions of the cable network in a multiple conduit run. Potential measurements made in manholes are subject to wide variations which may be traced to many causes. This factor was one of the authors' principal reasons for their investigation of more precise and convenient methods of making sheath current measurements on multiple cable networks.

Duct Surveys

Duct surveys have been in use for many years and in some localities have been the principal tool used by the engineer in his corrosion analysis work. However, experience through the years indicates that serious deficiencies exist in this method of obtaining

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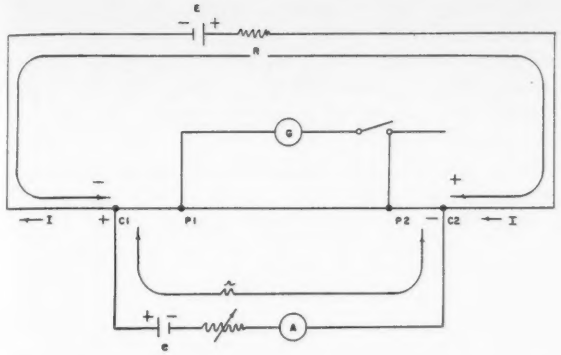


Figure 1—Fundamental circuit of the Zero Resistance Ammeter method of measuring current in a closed circuit without disturbing the physical makeup. If E is the potential driving the current I through the closed circuit C2, P2, P1, E, the resistance of which is R, the current entering point C2 is equal to the current leaving point C1; if $\frac{e}{r}$ is made equal to $\frac{E}{R}$ then i is equal to I but of opposite polarity; therefore, no current will flow through the section between C1 and C2. This condition of balance will be indicated by zero deflection of the galvanometer "G". Ammeter "A" will then indicate the value of the current I flowing in the closed circuit.

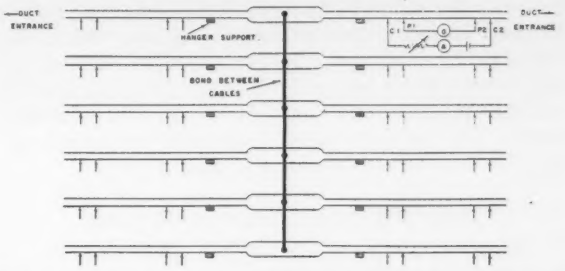


Figure 2—Typical arrangement of cables in a manhole of a multiple conduit system. Arrows indicate points where sheath current measurements are made.

data for analysis. The deficiencies of the duct survey method and the high cost of obtaining data in this manner, provided additional impetus to the investigation of better methods of making sheath current measurements and using the data in the analysis of corrosion condition.

Survey work done on the underground cable network in Buffalo in 1950, immediately after trolley operation was discontinued, indicated the need for improvement in testing procedures and instrumentation. Low resistance voltmeters used for stray current measurements were replaced with high resistance meters for potential measurements. Lead-lead chloride and copper-copper sulfate electrodes replaced the time-honored conventional lead plate as the earth contact electrode. Sensitive millivoltmeters capable of indicating 0.01 millivolt per scale division were brought into everyday use. Many duct surveys were made in manhole sections where recent cable failures had occurred.

The analysis of the duct survey data indicated poor correlation with the location of the corrosion attacks on the failed cables when they were inspected after removal from the ducts. The investigation of this lack of correlation prompted early experiments in the measurement of sheath current on each individual cable in the network.

The first opportunity to subject the theory of current loss analysis to a good test came when a pressurized cable installed for only four years developed a leak in a manhole section where three corrosion failures had occurred in less than two years. The authors were able to make sheath current measurements on the entire cable network in the manholes on each side of the section in which the cable was failing before the cable was replaced or the network disturbed in any way. Sheath current measurements were made between the duct end and the splicing sleeve on each cable. Measurements were made simultaneously in both manholes so that conditions changing with time would not affect the results.

Millivoltmeters having a sensitivity of ten ohms per millivolt were used for making the measurements. Values were recorded to the nearest 0.005 millivolt which was indicated by one-half of a scale division on a 100 division one millivolt scale. Resistance values used in the current computations were obtained by careful measurement of the section length over which the millivolt drop was measured and the outside diameter of the cable. This information was referred to tables containing resistance values per unit length for lead cable sheath and these values were used for computation of the current. This method of determining resistance for the current computation is far from precise, to say the least, because of the variations in sheath thickness permitted by normal manufacturing tolerances and the difficulty of making precise measurements of the diameter and length of the test section in the manhole.

Using the methods described, crude as they may be, the authors were able to determine that about one-half ampere of current was being lost in the manhole section on the cable network consisting of five lead cables, all approximately two and five-eighths inches in diameter. Further analysis of the measurements indicated that about 300 milliamperes were being lost on the cable that indicated an air leak in the manhole section. The other 200 milliamperes of current loss were distributed about equally over the other four cables. The air leak in the failing cable was small and the cable was left in place under constant surveillance for several weeks while a new section length was being secured for replacement. During this period the initial tests were repeated several times with the results remaining consistent with the previous tests. The magnitude of the total current flowing in the network and the current lost in the section varied as much as 20 percent, with the ratio of current loss on the failing cable to current loss on the good cables remaining almost constant. When the failing cable was removed, severe corrosion attack was found over about 60 feet of the sheath.

The results of the tests just described indicated that much valuable information could be obtained from the analysis of sheath current measurements in multiple cable networks. The method used to make

the tests left much to be desired from the standpoint of both accuracy and economy. At this point the authors began to give serious thought to the requirements for a practical and accurate method of making large numbers of sheath current measurements. Several different circuits and equipment arrangements were designed and field tested.

Zero Resistance Ammeter Method

The most promising method of measurement proved to be what has come to be known as the "Zero Resistance Ammeter Method." The basic circuit is illustrated in Figure 1.

In this method the potential drop over the test section of cable sheath is observed with the galvanometer "G" which is used as a null indicator and to determine the direction of current flow. In making the measurement a direct current potential of opposite polarity to the potential appearing across points P_1 and P_2 is applied across points C_1 and C_2 under control of resistance R and adjusted until the galvanometer indicates a null. At this condition of balance there is no potential drop across P_1 and P_2. The current indicated by ammeter A is the current required to produce the zero potential drop and therefore is equal to the current that flowed in the test section, between points P_1 and P_2. The electrical characteristics of this test circuit are dealt with in another part of this paper and an equipment arrangement is presented with sufficient simplicity and accuracy to permit the average field tester to obtain measurements suitable for analysis of current loss or pickup.

Figure 2 illustrates a typical group of cables in a manhole serving a network of underground cables. Electrical bonding of the cables is carried out by placing a low resistance connection between each of the splicing sleeves as shown on the drawing. The splicing sleeves lie between two supports secured to the manhole wall. In normal practice the cables do not contact the manhole wall or other cables between the supports and the entrance to the duct. Under these conditions it is generally possible to obtain a minimum of about two feet of cable over which the current measurement can be made.

Figure 2 indicates schematically the points where measurements would be made. In making current measurements by any method, it is imperative that no leakage paths exist, to ground or other cables, between the terminal connections to the cable sheath. It is fully appreciated that conditions as readily adaptable to this method of measurement as those shown in Figure 2 do not prevail in every manhole. However, if it is important that a current measurement be made, it is generally possible to temporarily rearrange the cables in such a manner that a leakage-free section can be obtained.

Figure 3 is a typical diagram on which current measurement data has been posted for analysis. The cable network has been reduced to a simple electrical schematic. Current magnitudes are shown in amperes with arrows indicating the direction of flow in the network. Applying simple arithmetic to the currents entering and leaving the common points at the manholes, it appears that either Kirchoff's Laws do not hold or that the measurements are not consistent enough to be reliable. The sum of the currents entering the electrical center point is not equal to the sum of the currents leaving it in any of the manholes shown.

When the factors contributing to the discrepancy are considered, this development is not surprising. In some cases the arrangement of stub cables is such that it is impractical to measure the current in them. These cables form circuit branches conducting current to or from the electrical center. The hanger supports on each side of the splicing sleeve provide a leakage path to ground on each side of the electrical center. The effect of the latter can be eliminated by insulating the cables from the supports. Investigation of the effects of insulating the cables from the racks indicates that if there are no other factors, such as cables, on which measurement is impractical, contributing to the discrepancy, it can be reduced to the order of two to five percent. This difference is within the order of precision obtainable with the other components of the measuring circuit.

The chief concern of the corrosion engineer is the loss of current from the cable sheath in the duct section between manholes. The validity of the measurements taken adjacent to the duct in the manholes on each end of the section under test is not affected by the leakage path formed by contact with the supports. In extreme cases it may be advisable to make simultaneous measurements on the cables at each end of the section. This would eliminate the effects of stray currents or variations caused by conditions changing in the interval between the two measurements.

Corrosion engineers also have shown concern over the fact that wet manholes must be pumped in order that workmen may enter them to place the test connections on the cables. This produces a change in the leakage path to earth in the manhole and, to some extent, in the conduits. Few tests have been made to date that furnish information accurate enough to determine the validity of this concern. It is the opinion of the authors that simultaneous measurements at each end of the section under test made immediately after pumping the manholes will produce measurements of sufficient accuracy to permit valid analysis of current loss or pickup. As an alternative in extremely critical cases, the test connection may be soldered to the cable sheath and the test section insulated with PVC tape or by some similar method to eliminate the leakage paths between the test connections. The test leads are terminated in the rim of the manhole directly under the cover and the water level condition is allowed to return to normal before tests are made. This procedure would permit observation of the sheath current under normal water level conditions much in the same manner that duct surveys are now made in normally flooded conduit sections.

The foregoing material has been presented as a record of experiments and experiences with sheath current measurements and their use in corrosion analysis. The authors do not proclaim a Utopian

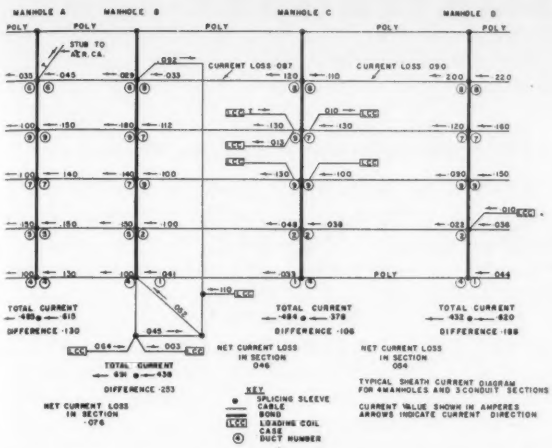


Figure 3—Typical sheath current diagram for four manholes and three conduit systems.

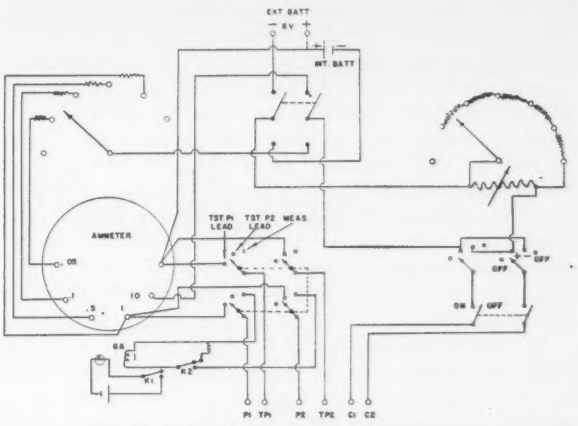


Figure 4—Simplified schematic Zero Resistance Ammeter test set (Electrical Instrument Laboratories, Buffalo, New York.)

solution to the problem of finding where and when cables will fail. There is, of course, nothing new or startling in the fundamentals involved. They are merely an application of Ohm's Law while null measurements using galvanometers are in the literature of Kelvin's day. The purpose then of this manuscript is to call to the attention of the corrosion engineer a different approach to the problem of measuring the current flowing in an underground structure. It is hoped that these data will stimulate the thinking of others and encourage further experiments with this method of measurement. Much data taken under all types of conditions is needed for thorough and critical analysis before any attempt should be made to lay down ground rules for the translation of current loss into probabilities of cable failure.

There are of course certain limitations in the current loss analysis technique. Measurements made in adjacent manholes indicating no current loss in the section do not guarantee that cables will not fail in that section. It is possible for currents to enter and leave the cable section between the two manholes, giving no indication at either end. Sections in which there are several other structures crossing the duct line at various locations are particularly vulnerable to this condition. The method presented here is another useful tool for the corrosion engineer but like all engineering tools it must be applied with good engineering judgment.

The most important feature of the Zero Resistance Ammeter method of measuring cable sheath current is that it is not necessary to determine the resistance of the cable sheath on which the measurement is being made. In the measurement of current by the potential drop method, it is mandatory that this resistance be determined to a high degree of accuracy if current values of the order of milliamperes are to be measured. Otherwise, errors may be introduced that would exceed the magnitude of the current flowing in the sheath. It has been pointed out in a foregoing paragraph that accurate determination of sheath resistance over a short section is almost impossible.

Electrical Problems Involved in the Measurement of Small Currents in Very Low Resistance Currents

Conventional current measuring instruments generally utilize a millivoltmeter to measure the voltage dropped across a shunt. To use such an instrument it is necesary to open the current carrying circuit and insert the shunt and indicator or, in the case of relatively small values of current, insert the indicator only. This method cannot, of course, be used when it is impractical or impossible to open the current carrying conductor.

The current in such a conductor can be determined if its resistance is known within the required limits of accuracy and if a millivoltmeter of the necessary sensitivity and precision is at hand. In this method, the conductor itself becomes the shunt and the millivoltmeter, together with its leads, becomes the current indicator. The current in the conductor will be the indication in volts divided by the resistance of the section of the conductor across which the voltage drop is read. In this method the accuracy of the result depends upon the accuracy of the resistance figure for the conductor, the readability of the millivoltmeter, the amount of contact resistance in the millivoltmeter circuit, the amount of the thermo-electric potentials in the millivoltmeter circuit, and the degree of temperature compensation in the millivoltmeter.

The resistance of the conductor will be affected by variations of temperature, cross sectional area and the material itself. When the current is low and the resistance of the section of the conductor is low, the voltage drop to be measured may be only a few hundredths of a millivolt. The readability for values, such as these, even on a range of zero to one-half millivolts is very poor. Introduction of contact resistance and thermo-electric potentials can be minimized by a careful operator. Thermal compensation of the millivoltmeter is the concern of the instrument manufacturer but this becomes increasingly difficult as the range is reduced.

The method to be described uses a conventional multi-range ammeter as the current indicator and a

sensitive galvanometer as a null indicator. Basically, the only other requirement is a current source capable of supplying the maximum current to be measured and adjustable over the range. This equipment is connected as shown in Figure 1. In use, the circuit through e and r provides an alternate path for the current which flows in the circuit under test. If the current in this alternate circuit is adjusted so that no voltage appears across points P_1 and P_2, it follows that no current is flowing in this section of the conductor. All current entering point C_2 from the source ER is accounted for by the current flowing in the alternate circuit. This current is indicated directly on the ammeter.

As the galvanometer is used as a null indicator only, the accuracy of the measurement is not affected by small variations in its circuit resistance. For this service a suspension type instrument without temperature compensation may be used. A detector of this type is most satisfactory from the standpoint of sensitivity, economy and freedom from bearing trouble.

The instrument shown in Figure 4 contains a five range ammeter and a galvanometer with a sensitivity of approximately two microvolts per millimeter. The switches and keys provide means for range change, polarity reversal, current control and test of the galvanometer lead circuit resistance. The original model has been in field service for approximately one year and has required no service other than battery replacement during that time.

It is interesting to note that while a galvanometer is basically a current detecting device, the requirement here is for voltage sensitivity. This means that the galvanometer coil resistance should be low so that maximum current will flow through it. However, low resistance is not the only requirement as both resistance and current sensitivity are directly dependent on the number of turns on the coil. The restoring force inversely affects the sensitivity but as this force is reduced, the galvanometer becomes more fragile. In making a selection, consideration should be given the service conditions as well as the sensitivity.

The galvanometer sensitivity required to produce a deflection of .25 millimeters for a two milliamperes change in current in a two and five-eighths inch diameter lead sheathed cable two feet long is easily computed:

.000234 (resistance of section of cable) multiplied by .002 (current change in amperes) equals .000000468 volts.

If this value is to equal .25 millimeter deflection, a sensitivity of two microvolts per millimeter is approximately correct. While it might appear that .25 millimeter is a very small deflection, by this method this deflection need not be read but only observed. In the case of a millivoltmeter with a range of one millivolt and a scale six inches long, two milliamperes in the same cable section will produce a deflection of .468 microvolts or about .07 millimeters, and here a value must be assigned to the deflection at the rate of 28.6 milliamperes per millimeter.

Thermo-electric voltages are an important consideration regardless of which of the two methods under discussion is used.

If a thermo-electric voltage is produced at point P_1 or P_2 or at any point in the circuit through the galvanometer, it is added directly to the voltage to be observed. Care should be taken to keep such interference as small as possible. The voltage developed with a copper-lead couple at ordinary temperatures is in the order of three microvolts per degree Centigrade. With copper leads connected directly to the lead cable sheath, it is apparent that a temperature difference of one degree Centigrade across points P_1 and P_2 would produce the same potential as a sheath current of 12.8 milliamperes.

A contact arrangement to minimize this source of error is under development. The requirement is for an exactly symmetrical assembly that will produce thermal voltages only at points where an equal voltage of opposite sign is also produced. Work has progressed on a system in which the leads from points P_1 and P_2 are brought out from the cable sheath through lead wire to a point where they can be made to assume the same temperature and there joined to copper. Indications are that if a suitable mechanical arrangement can be made, this method will be satisfactory.

Any discussion of this article not published above will appear in the June, 1957 issue.

Publication Number 57-1

Fifth Interim Report

Stray Current Electrolysis

Technical Unit Committee T-4B on Corrosion of Cable Sheaths*

Prepared by Task Group T-4B-6 on Stray Current Electrolysis*

Introduction

TASK GROUP T-4B-6 has been assigned the task of collecting and compiling a record of methods of cable bonding, draining to railway substations, booster drainage reverse current switches, insulating joints, bonding to other utilities. This is a report prepared by the task group presenting information included in replies to a questionnaire on "General Practices Pertaining to Bonding and Grounding of Cable Sheaths for Corrosion Mitigation" that was circulated among twenty companies in the utilities industry.

Companies that Replied to the Questionnaire:

Bell Telephone Laboratories, Murray Hill, New Jersey
Boston Edison Company, Boston, Massachusetts
The Cincinnati Gas and Electric Company, Cincinnati, Ohio
Commonwealth Edison Company, Chicago, Illinois
Commonwealth of Australia, PMG Department, Melbourne, C. I., Australia
Consolidated Edison Company of New York, Inc., New York, New York
Consolidated Gas Electric Light & Power Company of Baltimore, Baltimore, Maryland
Dallas Power and Light Company, Dallas, Texas
Department of Water and Power, Los Angeles, California
The Detroit Edison Company, Detroit, Michigan
Illinois Bell Telephone Company, Chicago Area, Chicago, Illinois
Illinois Bell Telephone Company, Midstate Division, Chicago, Illinois
Iowa Illinois Gas and Electric Company, Davenport, Iowa
The Ohio Bell Telephone Company, Cleveland, Ohio
Ohio Edison Company, Akron, Ohio
Omaha & Council Bluffs Electrolysis Committee, Omaha Public Power District, Omaha, Nebraska
Pennsylvania Power and Light Company, Allentown, Pennsylvania
Philadelphia Electric Company, Philadelphia, Pennsylvania
Southern Bell Telephone and Telegraph Company, Birmingham, Alabama

The committee appreciates the cooperation of these companies in making it possible to gather the information for this report.

Abstract

Data collected from 19 companies operating power and communication cables indicates that:

1. Communication cables generally are bonded at each manhole.

2. Communication cables may be bonded to other subsurface structures to equalize potentials. Frequently this follows joint electrolysis surveys when the installation is made after agreement is reached among the owners of affected plant. Local electrolysis committees are useful in these agreements.

3. Bonding of power cables usually is done to prevent personnel hazard from fault currents, to insure low impedence path of fault current return, aid in corrosion control, reduce sheath losses on single-conductor cables and reduce noise in communication circuits. Size of bond wire is related to probable fault current. **3.6.9**

Summary of "Bonding of Lead Cable Sheaths for Communication Cables"

This summary was prepared by Work Group T-4B-6, M. B. Hart, Illinois Bell Telephone Company, Chicago, Illinois, chairman with T. J. Maitland, American Telephone & Telegraph Company, New York, New York; A. F. Minor, American Telephone and Telegraph Company, New York, New York and F. E. Stetler, Wisconsin Telephone Company, Milwaukee, Wisconsin, members.

A. Bonding of Communication Cable Sheaths to Each Other

Sheaths of communication cables are bonded together at each manhole for protection against lightning, power system faults and to equalizing DC potentials.

The non-metallic covered types of communication cables usually contain a metallic inner sheath under the outside insulation which may be bonded at each manhole in the same manner as lead covered cables.

A flat tinned copper ribbon (3/8-inch wide, .051-inch thick), equivalent to a No. 6 conductor is used commonly to bond communication cables at each manhole. At drainage points the bonding ribbon used for normal cross-bonding may be increased to a size suitable to handle the heavier currents.

B. Bonding to Other Subsurface Structures and to Power Company Neutrals

Communication cables may be bonded to other subsurface structures to equalize potentials among them. Practices vary in different places and with different companies. In general, any proposed bond of this type is treated individually. A joint electrolysis survey and agreement as to bonding details is required in each case. Bonding to power company multigrounded neutrals or to power cable sheaths which are in turn bonded to water pipes may introduce special problems. The effectiveness of insulating joints in the communication cable system thus may be nullified. If a cathodic protection system is involved, it may be necessary to place resistors in the bonds to provide proper distribution of the protection current. This requires careful joint tests and cooperation to insure maximum protection for all plant involved.

Summary of "Bonding and Ground of Lead Sheaths for Power Cables"

This summary was prepared by Work Group T-4B-6B, R. I. Perry, Commonwealth Edison Company, Chicago, Illinois, chairman with A. R. Eaches, Philadelphia Electric Company, Philadelphia, Pennsylvania; F. E. Kulman, Consolidated Edison Company of New York, Inc., New York, New York; L. O. McCormick, Baltimore Gas & Electric Company, Baltimore, Maryland; J. B. Prime, Florida Power and Light Company, Miami, Florida and A. A. Sinclair, Detroit Edison Company, Detroit, Michigan, members.

Bonding and grounding of metallic sheathed underground power cables is necessary for one or more of the following reasons:

1. To minimize hazard to personnel and equipment during normal operation and from electrical faults, lightning etc.

* Irwin C. Dietze, Department of Water & Power, Los Angeles, Cal., chairman.
** J. Svetlik, Northern Indiana Public Service Co., Hammond, Ind., chairman.

2. To insure a low resistance or impedence path for fault current return.
3. To aid in corrosion mitigation.
4. To reduce sheath losses in large single-conductor cables.
5. To obtain reduction of noise in communication circuits.

Underground lead sheathed power cables are, in most cases, bonded to each other and connected to grounding mats at generating stations and substations and also to neutral conductors in manholes and vaults. Adequate bonding and grounding will increase safety for personnel and property and improve operation and continuity of service.

Bonding of the cables in manholes is very important in stray current areas to prevent electrolysis caused by DC potential differences between the sheaths.

The sheaths of the following cables may be bonded together at each manhole: Multiconductor cables carrying AC, and single or multiconductor cables carrying Edison DC (positive and negative). Auxiliary cables such as control pilot, pressure cables, etc.

Some power companies classify cables according to voltage and bond only the sheaths of each class of cables together, except in selected manholes.

Special bonding may be required for single-conductor cables of three-phase circuits where each cable is installed in a separate duct in order to limit AC sheath currents (circulating currents) and voltages during normal operating conditions. Special insulating sleeves are used to break the sheath continuity at spaced intervals and the isolated sheath sections are then either transposed by cross bonding or bonded by means of special sheath bonding transformers. Either bonding method will provide a path for AC fault currents and DC drainage or cathodic protection currents.

Cable sheaths provided with bonding transformers may be bonded to other structures at any or all bonding transformer neutrals. Sheaths of cross bonded cables can be bonded at the grounding points only. If cross bonded cables are to be bonded to other structures, special equipment may be necessary (bonding transformers will be required if the connection is not made at a grounding point).

Bonding trees or series bonding are used normally to bond cable sheaths together in manholes and vaults.

The size of bond wire used is dependent on the magnitude of the fault currents that may be encountered. In most cases bare tinned stranded copper conductors ranging in size from No. 6 to No. 0000 are used. Insulated bonding wires are used for cross bonding and to connect sheaths to bonding transformers in order to prevent short circuiting the cable sheaths.

Section A—Cable Bonding, Bonding to Other Utilities, and Insulating Joints

Question A

1. Does your company have a set of bonding and grounding specifications? If so, will your company submit a set of these for study by this committee? Otherwise, will you outline your bonding and grounding procedures for us?

Company

A. We have standard specifications for bonding lead sheath cables to each other in manholes to assure fault current return and to prevent hazardous potential differences under fault conditions. We have no standard specifications for electrolysis drainage or grounding. Cases of electrolysis trouble are analyzed individually and specific corrective measures are adopted in each case according to conditions encountered.

B. The telephone company operates in accordance with Bell System practices. The street railway company has no specifications. The power district bonds all cable sheaths together and grounds in each manhole and at each terminal pole. No specifications are available.

C. Yes. This specification provides for the bonding of feeder cable sheaths at all manholes with No. 4/0 AWG 19-strand, bare tinned conductor cable, specifying bonding and grounding in manhole, vaults and service boxes.

D. Outline of bonding and grounding procedures: The sheaths of lead covered cables in all manholes shall be bonded electrically, as specified in the following instructions, to protect against possible harmful action of stray or induced currents. Cables are divided into three groups as follows: (Multiple conductor cables carrying AC transmission or distribution circuits). Group E: Single or multiple conductor cables carrying Edison DC (positive and negative) circuits not included under group S below, telephone, pressure, pilot, control, steam gauge, etc., cables. Group R: Six-hundred volt DC street railway feeder cables. Group S: Single-conductor cables carrying AC at 4800 volts or more.

Bond together the sheaths of all Group E cables.

Do Not Bond the sheaths of Edison DC neutral cables. These must be kept insulated from ground and all other cables as much as practicable.

Bond together and to Group E, the sheaths of all foreign cable (fire alarm, police signal, telephone, etc.) in every manhole. A single such cable, less than ½-inch in diameter, need not be bonded unless specially ordered.

Bond together sheaths of Group S cable sheaths only at station or feeding end, except as specified below under "Buried Cable" and "Grounding of Cable Sheaths."

Allow no metallic connections between Group E, R and S

Bond the armor of armored cable to the lead sheath wherever it is made discontinuous by a joint in the cable (whether in manholes or buried).

E. No.

F. Yes.

G. No. Each case is considered individually.

H. No.

I. Yes.

J. Bonding and grounding specifications are sketchy. The aim and purpose has been to be sure that all conducting objects with which persons may be in contact and which might conceivably assume different potential are substantially tied together.

K. The lead sheaths of all cables are bonded to a solidly grounded neutral. The neutral is grounded in all transformer vaults.

L. Yes.

M. No.

N. We do not have a complete set of bonding specifications. In general, our bonding practices are as follows:

a. *Low Voltage Cable Systems, 4800 V to 120 V:* In each manhole all lead cable sheaths are bonded together in one end of the manhole with a 2 x ⅛-inch lead strip which is soldered to each cable.

b. *Medium Voltage Cable Systems, 34.5 KV:* All cables in the same conduit line are bonded together with a No. 2/0 tinned copper cable. Where the cables terminate in each distribution station they are bonded to the galvanized riser conduit and the station ground.

c. *High Voltage Cable System, 138 KV:* Cable sheaths protected by cathodic protection systems, (details of these systems will be furnished if desired. However, subcommittee 16-C probably will cover this system).

d. *On Pole Risers:* All cable sheaths are bonded to the upper end of the galvanized conduit with a 2 x ⅛-inch lead strip. On service conduits, all lead sheaths are bonded together to the copper neutral and the conduit in the terminating pull box or switchboard on the consumers' property.

O. Yes.

P. Yes.

Q. Following is an outline of the cable bonding and grounding specifications and procedures in use:

Lead sheaths of all company cables in the system are bonded together in every manhole or vault unless some specific condition exists that would make such bonding unwise. Company cables are not bonded to foreign cables or structures until sufficient tests have indicated that such bonding is advisable and mutually agreeable. At risers all lead sheaths are bonded to the top of the riser pipe and to all grounds on the pole or structure unless some specific conditions make such bonding unwise. In case a cable terminal is equipped with a cable entrance having a gasket between the body and entrance, a bond is installed between the terminal body and the cable sheath.

In manholes and vaults bonds to cables are made at a point not more than 4 feet from the duct mouth. The length of bond wire is such that 18 inches of slack is available, the slack wire to lead away from the cable at the bond wipe and not allowed to remain near or touch the sheath at any other point.

Bonds are made with No. 2/0 extra flexible bond wire consisting of 133 tinned copper wires of 31.6 mils diameter. When making a bond connection the strands of the wire are untwisted and trained to parallel positions in order to increase the area of the wire in contact with the sheath. All cut ends of the bond wire are thoroughly tinned with solder, completely covering all exposed copper.

In making a bond to a cable sheath a wipe, of not less than 3/16-inch thickness, is built up where the bond is to be attached. The bond wire is temporarily secured in place on the built-up area and a second wipe made over the wire. All temporary holding materials are then removed and the bond wire trained directly away from the cable. The connections between bond wire, when necessary, are made with straight split copper connectors with all surfaces tinned.

Underground lead covered transmission and distribution cables not connected to another grounding system are grounded by connecting to driven galvanized steel ground

rods. Such grounds are intended to improve control of fault currents which may endanger personnel and equipment.

One 10-ohm or less ground is used for each cable 500 feet or less in length. For cable lengths greater than 500 feet the cable is grounded at each end with enough additional grounds so that no two are more than one half mile apart. Lightning arrester grounds are not connected to the lead sheath of short underground cable.

R. No.

This company uses the grounded Y system and our cable sheaths are grounded at substations, connected to the cases of all underground transformers, connected to the primary neutral and connected to the secondary neutrals on underground services.

Following are cable sheath bonding procedures:

a. No. 6 tinned copper ribbon is used.

b. The bond ribbons are formed or wrapped around the circumference of the cable with the end brought away perpendicular to the length and circumference of the cable.

c. The bond ribbons are wiped onto the cable sheath (not soldered).

d. Used: One ribbon around 4 KV cable sheaths. Two ribbons around 13 KV cable sheaths. Three ribbons around 26 KV and 33 KV cable sheaths.

e. All cables and bare neutrals are bonded together in all manholes, either by running bond ribbons between cable sheaths or by means of a bonding bus.

f. Practice of soldering the ribbons onto secondary cables and street light cables is permitted. However, the ribbon is brought away perpendicular to the length and circumference of the cable. These classes of cables are the only cables not reproofed.

S. No reply.

T. No. All cables in a manhole are bonded together to obviate interchange of current between adjacent cables. This bonding is carried out with a 1-inch strip of 7 lb. lead sweated to each of the cables. With armored cables, it is the practice to bond the steel tape armoring to the lead sheath at each manhole and also at cable terminal poles.

Question A

2. Does your company have a set of specifications for locating and installing insulating joints?

Company

A. Standard specifications are available for making sheath-ring insulated joints in sheaths of solid-type lead-sheathed cables operating at 13.2 KV and below. There are no standard specifications for determining under what circumstances insulating joints should be installed. Installation of an insulating joint at a particular location is made only after an electrolysis survey has indicated it to be the most suitable corrective measure. Such joints have been used only in very exceptional cases.

C. No specifications have been prepared for locating insulating joints in cable systems. However, insulating joints and crossing-bonding are installed in single-conductor cable of three phase feeders in which the phase cables are installed in separate ducts. These insulating joints reduce circulating sheath current and allow the current carrying capacity of the cable to be increased. The spacing between insulating joints is designed to prevent abnormally high sheath voltages during transient conditions (cable vaults) and to prevent voltages which might cause AC electrolysis during normal load periods.

Insulating joints are installed in cables supplying some railway substations to prevent excessive DC fault currents from burning the cables.

Insulating joints are installed where needed in conjunction with drainage cables in a few locations in order to obtain satisfactory correction of conditions caused by stray railway currents.

H. No. This company uses as a guide on this subject an article written by R. C. Waldron, Assistant to the Chief Engineer of the Okonite Company. The name of the article is "The Effects of Grounding Metallic Shielding and Sheaths on Insulated Power Cables."

I. In general, this company does not use insulated joints on any of its underground cable.

J. Insulating joints are used in a few consumer service lines only where it has been found that there is or may be objectionable flow of current.

L. Insulating joints are not used generally for mitigation of DC electrolysis on the system.

N. No. All joints on the 138 KV cable lines are purchased from the cable manufacturers with a built-in insulator, either porcelain or textolite, which have not given any trouble. Each line consists of three single conductor cables and in each manhole, two sheath bonding transformers are connected, one on each side of the insulating joint with both transformer neutrals connected together. DC resistance through the sheath bonding transformer is quite low, having very little effect on the DC sheath current of the cathodic protection system.

Q. Company specifications regarding insulating joints cover construction only and, in general, are used to control the flow of alternating currents rather than direct currents and the locations depend upon the merits of the situation.

Insulating joints are placed in single conductor cables, with proper cross bonding, to reduce induced sheath currents to a minimum. Some high voltage cables require a supply of insulating oil; in wet manholes insulating features are installed in the piping between the supply tank and the cable to stop the flow of galvanic current and alternating sheath currents.

R. The company does not use insulating joints except to reduce induced sheath currents on high voltage single conductor cables. These cables all are located at generating stations and substations.

S. No reply.

B, D, E, G, K, M—No.

F, O, P, T—Yes.

Question A

3. Can you furnish information as to bonding and grounding practices which you have used in the past and which have proven unsatisfactory or unsound and which should be avoided? Please explain.

Company

A. Use of bare copper conductor bonded to lead-sheath cables in the same duct bank has proven unsound because it has sometimes resulted in serious galvanic corrosion of the lead sheaths.

C. Lack of adequate bonding may result in sheath burning, especially in cables installed in iron ducts, and single conductor cables in common non-metallic duct. Inadequate bond in the vicinity of power sources (generating stations and substations) may result in sheath burning during fault conditions. Lack of bonding between cable sheaths in stray direct current areas may result in electrolysis of the cable sheath. Installation and maintenance of standard bonding has been found to result in correcting the above conditions.

D. In the past, cables were bonded as they are at the present time, but they were also grounded in each manhole.

The ground consisted of an iron rod driven through the floor of the manhole and connected to the bond bus by means of a copper wire soldered both to the bond bus and to the iron rod.

This practice has been discontinued long since as the ground acts as an antenna—thus tending to induce a great amount of stray current on the cable sheaths.

F. Bonding to adjacent plant for reasons other than legitimate stray current ties often can result in harmful galvanic effects. For this reason, bonds must be carefully considered and should be installed only if the electrolysis conditions on one or the other plant is improved. Bonds should not be placed if the plant receiving the current cannot conduct this current to the source via a metallic path.

I. The use of untinned copper wire has resulted in galvanic corrosion at the point of attachment to the cable sheath. No difficulty has been experienced in the use of tinned copper bond wire.

J. Very little electrolysis mitigation work has been done. Practically all grounding is safety ground of electrical device frames, conduits, tanks, etc. and to avoid having objects that may be contacted by persons at substantial differences of potential.

L. Trouble has been experienced in the past from galvanic action where a portion of the bonding wire was left in partial contact with the sheath for a short distance outside of the soldered connection. Under present bonding practices, the bonding wire is brought out of the soldered connection at right angles to the sheath. This has practically eliminated sheath corrosion resulting from improper bonding methods.

N. Use of a 2 x ⅛-inch lead strip for bonding has proved very satisfactory and is replacing copper wire installed years ago.

P. The company has learned that bare copper should not be used for bonds and that it is advisable to avoid acute angles between bonding ribbons and cable sheaths.

Q. Emphasis is placed on keeping the bond wire away from the cable sheath except at the wipe. Extensive corrosion has been found where the free end or slack in the bond wire made contact with the lead sheath, other than at the wipe, in the presence of an electrolyte. In these cases the chemical

action was: First, the removal of the tin from the bond wire due to a tin-to-lead couple, then the removal of the lead due to the copper-to-lead couple.

Corrosion of vital parts has been experienced because of the indiscriminate inter-connection with bare copper in grounding and bonding systems. Economical operating practices require some use of dissimilar metals in the ground. Some corrosion will result but detrimental action can be mitigated by the use of metals in the closely associated structures in such a way that the most vital structure is cathodic, by making the anodic metal surfaces large with respect to the cathode surface, and by increasing the electrical resistance (perhaps the length) of electrolyte path.

R. Practice of soldering bonding ribbons onto cable sheaths of large cables discontinued several years ago. It was found that the water and moisture between the cable sheath and the bond ribbon created galvanic cells which caused the cable sheath to corrode under the bond ribbon.

S. No reply.

B, E, G, H, K, M, O, T—No.

Question A

4. What is your policy regarding bonding to other underground structures, including pipe lines? How do you determine where bond and insulated joints are to be placed in your plant, and where and when your plant is to be bonded to other utilities?

Company

A. In general, practice is not to bond to foreign underground structures. An exception is occasional bonding to street railway negative return feeders when electrolysis surveys indicate such procedure is desirable. Also, bonds occasionally have been made between cable systems and structures such as bridges and railway metallic structures, primarily as a safety practice.

B. The power district has multiple water main grounds at substations and other locations for grounding purposes only. The street railway company has no grounds. The telephone company bonds to water only where the interchange of current is great and may cause damage, or where a hazard might exist and where such bond will not injure the water main.

Bonds are determined by study and the situation at each location. There is no bonding to structures other than the water mains and this, for corrosion mitigation, only to a very limited extent. Only about three such bonds exist in the city. The telephone company uses insulating joints on building services as required to eliminate pickup in buildings.

C. Policy on grounding the neutral of service cables to the water pipes is determined by National Electric Code.

Sheaths of the cable systems are bonded and drained by a drainage cable to railway cable sheaths, negative feeders and the negative bus of railway substations where necessary or desirable to mitigate electrolysis.

Electrolysis tests are made jointly with the representatives of the railway and other utilities concerned. A temporary bond is installed for test purposes. Data obtained with a temporary bond are analyzed jointly by the engineering groups and an agreement as to what mitigative steps (bonds, insulating joints, etc.) are undertaken. These are installed on a cooperative basis, each company undertaking the portion of the installation on its own property.

D. No bonding of cable sheaths to pipe lines.

Bonds are made to other cable structures in order to equalize potentials between them and foreign cable sheaths.

E. No reply.

F. As a general rule, buried plant is kept isolated as much as practicable from other substructures. Bonds are avoided whenever possible. Where bonds are a necessity, they are placed as close as possible to the point of exposure to the other substructure. Resistance of the bond is predetermined by test data and calculations to get the minimum current drain required, to reduce the effect of the exposure to a safe value. Insulating joints are placed at points where maximum current flow exists, but these, as bonds, are avoided if possible because additional problems often are created by their installation.

G. Bonds to other utilities are installed where cooperative tests indicate desirability. Since the underground plant is extensive, periodic testing is necessarily confined to known danger areas. Results of these tests determine where and when the plant is bonded to other utilities.

H. On multiple grounded sheaths, bond to other underground structures is made wherever possible.

I. Cables are bonded to other underground structures and other utility cables when it can be shown that such bonding is to mutual advantage. Location of such bonds is determined by cooperative sheath-to-earth potential surveys and measurements of current distribution along the cables affected. The tie is placed at the point where optimum protection is afforded all the cables involved. When cathodically protected pipe lines of other utilities are close to our cables, cooperative surveys are made to avoid undesirable over drainage.

J. Policy is to bond to other underground structures, as a purely personnel safety measure. However, this procedure is often objected to by the owners of the "other" structures, mainly because of possible electrolysis to the "other" structures.

K. Not used.

L. No objections to bonding to other underground structures, including pipe lines. Underground plant is bonded to other utilities after a joint investigation indicates that the interconnection will benefit one company and will not be injurious to the other company or to the other interested companies.

M. Bonding to the various underground structures including pipelines is only provided for when the result of a joint study of the various affected companies in the area indicates that a particular bond arrangement will produce the required results.

N. In a few cases buried plant is bonded directly to other utilities and only in cases where a few amperes is drained to help protect a telephone or telegraph cable. In each building or residence on 120-240 V distribution system lead sheaths of all cables and copper neutral are connected together and to the water service on the consumer's property. Plant also is connected indirectly to the gas company pipes through the water heater pipes.

O. Bonds are made to other utilities after joint tests have determined the location and size of the wire to be used. In most cases a limiting resistance also is used for the bond.

P. This company will bond to other utilities and permit them to bond to its plants where tests indicate one system will be benefited and the other not harmed.

Q. Company policy in the matter of bonding to other underground structures is that such bonds are not installed until after a complete survey of all structures affected and mutual agreement reached with interested parties.

In all these matters ("bonding to" or "insulating from" other structures) AC system fault currents and the safety of personnel are given top consideration. Permit for others to bond to company structures is given provided company interests are not jeopardized and any detrimental condition so created is corrected.

R. Bonds to other structures are usually made under the following conditions:

a. When the installation of a bond will equalize potentials between two or more structures without causing undesirable structure-to-earth potentials when receiving current from the other structure or structures.

b. When forced drainage or cathodic protection is applied to one structure causes earth potentials of adjacent structure to:

1. Become less negative to earth. A bond usually is not considered necessary because the reduction in negative potentials is usually attributed to the reduction in polarization from the structure being drained.
2. Change from a negative potential to a positive potential to earth. A resistance bond is installed to bring the offended structure back to a safe negative potential.
3. Become more positive to earth. The company owning the adjacent structure is invited to make a joint drainage installation and share in the costs. In the event this is not acceptable to the other company, a resistance bond is installed and the adjacent structure is brought back to the same potential as it was before the application of forced drainage.

S. No reply.

T. It is the practice to avoid, in all cases, bonds between telephone cables and other structures such as pipe lines.

Question A

5. To what extent do you use insulating joints in the control of corrosion of underground plant?

Company

A. Limited.

B. The telephone company uses insulating joints in buildings.

C. Insulating joints are used for corrosion control on the underground cable system only in a few cases. Sheath continuity for fault currents is indispensable for system operation. This rules out the widespread use of insulating joints.

D. None.

E. No reply.

F. Insulating joints are used to avoid metallic contact to other plant, such as pipe lines and power cables. Occasionally they

are used to prevent current flow into a dip or lateral in low-earth potential areas, and sometimes they are used to prevent pickup of stray current which cannot be conducted metallically to its source. In cable entrances to buildings, insulating joints are used to avoid contact to other plant such as pipe lines and power cables.
G. Insulating joints are used to isolate areas where mitigative measures are taken.
H. None.
I. Have used an insulating joint in corrosion control on one occasion in connection with the magnesium anode installation. The line protected by this magnesium has been abandoned since.
J. Seldom.
K. None.
L. Seldom.
M. Insulated joints have been used in specific areas to isolate insulated lead covered cable sections within a specific area subject to stray currents.
N. Only in occasional cases such as to break the galvanic couple between copper and steel pipes, such as at a water heater.
O. Insulating joints are used in all central offices in which the cables enter from the underground conduit system and in aerial cable entrances in stray current areas. The insulating joints also are placed in cables entering subscriber premises to limit possible current flow from building structures.
P. Specifications require that all cables entering buildings shall have insulating joints to prevent the flow of stray currents to the underground plant. In addition, insulating joints sometimes are used to isolate certain sections of underground cables when those sections are to receive special treatment, such as cathodic protection, etc.
Q. Insulating joints are used in certain cable sheaths for the control of induced alternating currents and in oil-pipe and accessory connections for control of AC and galvanic currents. Insulators have been used between component parts of station ground systems to force railway currents over specific connections to provide for further control and metering.
R. None.
S. No reply.
T. Only in special cases.

Question A

6. What problems in bonding and grounding do you have on which you would like information from others as to their experiences?

Company

A. Interested in general practices and experiences of others in grounding and bonding cables. In particular, would like to know the experiences of other utilities in intermediate and terminal grounding of pipe-type cables and the use of step-voltage cells at pipe-type cable terminal.
C. Additional information is desired on the probable effects of alternating sheath voltages in causing AC electrolysis on single conductor feeder cables.
F. The use of insulating joints to sectionalize cable runs in order to minimize cable potentials and current transfer. Also interested in the effect of such sectionalizing on cable branches and extensions from the main cable runs. These include problems on laterals and underground dips removed from the main underground runs. Have had numerous failures of cables branching from main runs exposed to transit stray current and are considering insulating joints to remedy this condition, and would like to know what experience others have had with this application.
G. No specific problems exist, but experiences of others would be of interest.
I. At present major problems are due to stray direct current which exists in those areas in which street railway lines with rail returns have been supplanted by trackless trolleys. In these areas the protection given by rail returns has vanished and other methods must be introduced to combat electrolysis of cables. Magnesium anodes are, in general, unsatisfactory because of the large currents required for protection. Since cables are bonded to municipal water pipes at every service, it is necessary to drain not only cables, but also all of the water pipes in the area served by the company. Current requirements for such drainage are so great that the use of magnesium is not economically sound.
J. Problem includes every conceivable situation because company operates electrical, gas, district steam heat distribution systems. Little attention has been given to the matter.
L. Special bonding to reduce the amount of stray DC current flowing in the phase wires of a 4 KV distribution system having a multi-grounded, or common secondary and primary neutrals, where 3-conductor primary cables are used. Also special bonding to limit the flow of DC in the secondary phase wires of a lead cable AC network system.
M. Would be pleased to have any information on cases where problems were solved on underground bonding and grounding, specifically in areas where local cells are in evidence.
P. Biggest problem in bonding and grounding has developed in the last few years with a) the decrease of electrical rail transportation, and b) the increase of power company's use of the common neutral system of distribution in which underground cable sheaths are tied to bare undrained water and gas pipes. As a result of a) there is a greater need for cathodic protection, and as a result of b) any such system that might be installed usually would be nullified by ties to the power company sheaths.
D, E, H, S—No reply.
B, K, N, O, Q, R, T—None.

Section B—Drainage to Railway Substations and Booster Drainage

Natural Drainage to Railway Substations

Question B

1. What is the greatest distance you have found it necessary to run a drain cable away from a railway substation to obtain proper drainage?

Company

A. 7000 feet.
B. 1400 and 1700 foot aerial drain wires are in service.
C. 3000 feet.
D. Four blocks from the substation.
F. No cable drains extended directly from the substation to cable plant removed from the substation. However, there are extended cable drains from well drained plant to cable plant for distances up to 2000 feet.
G. Due to the double-trolley street railway system, difficulties from this source usually are confined to the action of currents resulting from faults on the trolley system which can be located and corrected. Cable system drainage is seldom required.
I. 1821 feet of 1000 MCM R&B cable in a street railway duct.
K. Approximately 1000 feet.
L. 1780 feet.
M. No difficulty with railway substation drainage because the area served by the company has no street cars but trolley busses only. For these locations a single grounding point is specified at the substation, thereby preventing the normal rate of drainage evident in the street railway system type of installation.
N. Approximately 2 to 3 miles.
O. Approximately 4000 feet.
P. No reply.
Q. 9800 feet. One drain wire 8800 feet long was retired recently.
R. 6000 feet. This cable was installed originally as a 600-volt DC trolley feeder and was converted to a cable drain by the street railway company when its street car line which paralleled the cable line was converted to bus operation and street car rails removed. The greatest distance actually installed as drain cable was 660 feet.
S. No reply.
T. Approximately ¾ mile.
E, H, J—None.

Question B

2. What portion of the above drain cable parallels or is in the same conduit line with existing cables?

Company

A. All but about 200 feet of 7000-foot drain cable is in the same conduit with existing cable.
B. None. One 600-foot run of drain wire is installed in conduit to reinforce the conductivity of lead sheath adjacent to a street railway substation.
C. Entire length.
D. About 50 percent.
K. Entire length.
L. Parallels and is in same conduit with other cables for its entire length.
N. Most of the drain cables are on pole lines.
O. 400 feet.
Q. None. One drain recently retired did parallel existing cable for 4300 feet.
R. All.
T. Most drain cables are on pole lines.
F, G, P, S—No reply.
H, I, J, M—None.

Question B

3. What type of insulation, if any, is on your drain cables installed in conduit lines? If bare conductors are used, did they cause any trouble?

Company

A. Insulation now used on drain cables is low-voltage rubber, Neoprene, or polyvinyl chloride. Obsolete or scrap paper-and-lead cables also are used for drain cables. Previously some bare copper drain cables were installed but no trouble has been attributed to these installations.
B. Weatherproof wire is used as drain cables. No trouble has been experienced. No bare wire is used.
C. Usually, drain cables consist of No. 4/0 Awg. or 500 MCM, rubber insulated, lead sheath cable. Bare conductors are not used.
D. Drain cables have paper and lead or rubber and lead insulation. In some instances bare wire has caused considerable trouble.
E. Always try to obtain cable with good insulation. However, old copper cables with the insulation deteriorated have been recovered with no trouble experienced.
F. In older installations, mostly weatherproof coating was used. These wires now are being replaced with a good quality insulated wire. New installations are carefully specified to consist of only the best insulated wire. Some trouble has been encountered from bare copper and weatherproof wires.
I. In general, R & B or weatherproof wire is used for drain connections. Bare negative returns used by the street railway have given some trouble because of the leakage which results in a current sink in the ground near cables. Policy of the street railway now is to install insulated negative returns.
K. Rubber insulated-Neoprene jacketed.
L. Paper insulated, lead covered cables. Bare conductors are not used for underground drainage cables.
N. In one instance reclaimed 500 M-1C-600 V LCC was used with duct splices wherein the copper conductors were bonded to the lead sheath in each splice. This was not too satisfactory because the drainage cable also picked up stray railway current which made it difficult to grade the drainage at specific points along the line with resistors. Insulated cables to drain the lead sheath of the drainage cable at points determined from the electrolysis survey are used now. Bare copper conductors are not installed at any time. Regular paper insulated cables for drainage bonds and neutral cables are used now.
O. Lead covered rubber insulated conductors have been used in the past and the weatherproof wire with a layer of tar saturated tape has also been used. Corrosion has been experienced on a few cables due to the poor insulation on the drain wire and this drain wire being placed in the same duct with the cable. This practice is not followed at the present time.
Q. Drain wires in conduit lines are insulated with material such as weatherproof and rubber, or rubber-like materials. Junk high voltage cables also have been used.
R. Generally for distances of less than 400 feet weatherproof wire is used, otherwise lead sheath cable is used.

In a few cases weatherproof drain wires are used on which the weatherproofing has deteriorated to the extent that it can be considered bare. These bare wires have not caused any corrosion problems.

T. Bare conductors are not used.
G, H, J, M, P, S—No reply.

Question B

4. Have you experienced any difficulties caused by overdrainage of street railway tracks to railway substations? (Usually caused by too many or too long track negative feeders.) If "Yes," how was this condition corrected?

Company

B. Corrected by using resistors in the negatives at street railway substations.
C. Cable sheath electrolysis has occurred in the vicinity of railway substation where the cable sheath potentials were positive with respect to the negative bus and rails. Drain cables were installed, with current limiting resistor if necessary. Controlled sheath drainage has been effective in correcting electrolysis.
D. Have had experience with the overdrainage of railway tracks, not caused by too long a track negative but by too short track negatives. Extend negative feeders.
F. This is not considered over drainage of rails, but an improved practice and desirable from the standpoint of reducing overall rail potential drop. This practice does not cause difficulties because where it is followed, drainage is through reversed current switches to the rail return point. Drainage always is taken at points of lowest track potential, which is at the rail connections to the negative bus of the substation. These rail connections are made by means of insulating negative feeder ties. Drainage conductors seldom are more than a few hundred feet in length and are connected to a suitable bond on the negative feeder.
I. In one area it is suspected overdrainage of street railway tracks has caused some failures. If this is so, it can be remedied by the street railway's use of smaller returns or by installation of a rectifier.
L. Yes. Condition not corrected.
M. Have had some difficulties in years past which were overcome by the automatically operated drainage connections at those locations which appeared to offer the best opportunity for drainage control. The drainage unit was disconnected at the time of current reversal.
O. Street railway tracks have not been overdrained in this company's area, rather the reverse is true, so difficulties from this condition have not been experienced.
A, E, K, N, Q, R, T—No.
G, H, J, P, S—No reply.

Question B

5. Have you experienced current reversals on cable drains connected to the negative bus of railway substation? If "Yes," how was this condition corrected?

Company

A. Yes. Where these instances were considered sufficiently serious, valve rectifiers were installed to prevent flow of reverse current.
B. Current reversals on cable drains have been experienced. In street railway substations, drain cables are connected to a drain bus which is connected to the negative bus through a switch which opens when the substation is not operating, thus correcting the current reversal condition.
C. Current reversals may occur on drain cables connected to the negative bus of railway substations. If the reversal is caused by scheduled shutdown of the station (as during night hours) the station attendant opens a knife switch installed in the drainage circuit. In other cases, where the current reverses during substation operating periods, automatic reverse current switches may be installed to prevent the flow of reverse current. In case the reversals are relatively infrequent or small, they are considered insignificant in causing electrolysis and the reverse current switch is not installed.
D. Yes, in two cases reverse current valves were used to control current reversals.
E. Yes. This trouble was corrected by using a current reversal switch.
F. No. Reverse current switches were used.
I. Current reversals are controlled by operation of an electrolysis switch which opens the drain wire at the railway substation by railway personnel at times when the flow of current is away from the railway substation. In two locations where cables drain to negative returns, magnetic contactors are installed in manholes and operated remotely from the railway substation at times of current reversal. No cable failures have been attributed to reversal of current on a cable drain to a street railway substation negative bus. Experience with railway substation drainage has been very good. For example, on 110 KV oil-filled cable line which is isolated from other company cables for most of its route, a drain to the street railway negative bus near one terminal of the line protects 5½ miles of cable.
K. No.
L. Yes. Reverse current switches are used.
M. No.
N. Yes. This is prevented by the use of reverse current switches, except in some cases the operator in the railway substation opens a four-blade switch which disconnects all the utilities from the negative bus.
O. Current reversals on cable drains were cared for by the use of an electrolysis switch.
Q. Yes. Reverse currents in a drain wire connected to the railway substation negative bus are corrected by adjustments of the positive bus voltage at this and adjacent substations and by the installation of reverse current (electrolysis) switches, or contactors installed in drain wires (at railway substations) controlled by the DC machine controls so that the drain is closed solid when the machine is on the line and open when the machine is off.
R. Yes. This condition occurs at four of the street railway company's automatic substations which operate at a lower voltage than their manual operated stations. Each of these automatic substations has two 2500 KW rotary converters and they are equipped with an automatic drain switch which normally closes when the station operates. However, they can be adjusted so that they remain open until both con-

verters are in operation. Periodic surveys of the amount and direction of drainage current are made and the automatic stations are adjusted so that they are shut down during light load periods.
T. No.
G, H, J, P, S—No reply.

Question B

6. Have you experienced any cable failures attributed to reversal of current on a cable drain to a street railway substation negative bus?

Company

B. No, but probably would have had not proper steps been taken to correct the condition.
E. Yes. Before switches were installed.
F. No. Not with good switch maintenance.
A, C, D, K, L, M, N, O, Q, R, T—No.
G, H, I, J, P, S—No reply.

Question B

7. Have you had any experience, good or bad, with railway substation drainage that you would care to mention?

Company

A. No.
B. Experiences since 1917 indicates that properly administered, street railway substation drainage is easiest, most effective and economical method of protecting underground plant.
C. Cooperative action among utility companies operating cable systems in the city of New York has been found to be effective in solving electrolysis and corrosion problems. The problem of stray current electrolysis is considered to be under control as the result of the installation of drainage cable and limiting resistors (where necessary) between the various systems and the railway substations. Only 5 percent of the cable failures occurring because of sheath corrosion are caused by stray railway current.
D. Usually trouble is encountered where a path of unequal resistance is provided in the negative feeder system or where the voltage of one station is raised and another nearby station is lowered, thus making the first mentioned station feed in the territory normally fed by the station operating on the lower voltage.
E. Drainage to railway substations requires very close supervision. In most cases current reversals will occur in the bond wire. This condition can expose large areas of plant and cause serious trouble.

F. Good:

1. Have had very good success with cooperative drainage and joint tests.
2. Solution of the problems encountered in drainage design and maintenance was facilitated by the formation of the Electrolysis Committee in Cleveland.
3. Have had good success in getting transit system to decentralize negative return pickup locations on the rails at the various substations.
4. There has been good success in isolation of negative return from ground and the complete elimination of transit strays at Akron and Youngstown.
5. Have had good results from application of equivalent network theory in the design of drainage wires.

Bad Experiences:

1. In Cleveland, rail is used as negative return for trolley buses. This causes transit operations to adversely affect stray current conditions.
2. Substation scheduling, in some cases, has produced adverse effects.
3. In Cleveland, limited east to west negative return ties result, practically, in a segregated negative return system. Loads on one side of the town are often fed by substations on the opposite side of town, resulting in a very circuitous negative return path.
4. Indiscriminate rail removals have resulted in aggravating the conditions due to the original deficiencies in the negative return circuit. This tends to worsen the situation by increasing stray current conducted on the underground plants and overloading the drainage circuits at the substation.
5. Transit conversion in Cleveland has resulted in dislocation of loads so that substations which originally were located close to their load areas now are at some distance from them. This also tends to increase stray current and aggravates the corrosion problems.

K. Some trouble has been experienced with weatherproof cables in conduit lines used as negative return cables. For several years all new cables installed for this purpose have been insulated.
M. In general, have had good results with railway substation drainage, particularly with the present method of operation where the DC system is grounded at one point only. In one or two instances difficulties were experienced in DC currents traveling through the 4 KV system neutral as a result of a ground being created on the 600-volt feeder.
N. All utilities and the two railway companies work together with excellent cooperation through our electrolysis committee. No changes are made by any party without the consent of the others concerned.
O. Have found that attachment of the drainage wire to the negative return at points between the negative bus of the machine and the tracks is a poor policy due to the overload of current that can be returned over the drainage wire. In some instances the current in the drain wire has been doubled and the electrolysis switch eliminated by extending the wire to the negative bus on the machine.
Q. Best results have been obtained when drainage to railway substation is possible. In some cases difficulties such as large current flows, large reverse currents and relative large alternating earth currents had to be solved to obtain the best results.
R. Most of difficulties have been concerned with stray current drainage from cable lines which are up to a mile away from the nearest street railway substation or street car rail.
T. The department works through co-operative committees with the traction authorities and experience on control of drainage generally has been satisfactory.
G, H, I, J, L, P, S—No reply.

Question B

8. Where lead sheaths are drained to a railway substation negative bus, what steps has your company taken to limit the flow of stray railway current in the primary wires of an AC distribution system using multi-grounded or common secondary and primary neutrals; also in the secondary phase wires of lead covered AC network system?

Company

A. From available records it appears that our company has taken no steps to limit the flow of stray railway current in the phase wires of our AC distribution or secondary systems.
B. Stray current in the AC distribution system has not been a problem.
C. As a rule it has not been considered necessary or desirable to take steps to limit the flow of stray railway current in secondary phase wires of the AC network system. In a few special cases, the effects of drainage near a railway substation are restricted to the high voltage feeder cables by opening bonds between the feeder sheaths and the secondary system for several manholes on each side of the drainage connection. The object is to lower the sheath potential of the feeder cable near the substations.

Secondary cables, being in higher and drier ducts, should not be affected adversely by this practice.
I. Since the company has not had much trouble with the flow of stray railway current in the primary or secondary system, no particular steps are taken to limit the flow of such current.
L. Reduced by the installation of resistance in the 4 KV neutrals in the substations and in the secondary neutrals in the AC network vaults.
O. In some cases telephone aerial cables have been tied to the multi-grounded neutral of the power company to eliminate a noise condition. Insulating joints have been placed between the aerial and underground cables to eliminate DC current flowing into the underground cable and overloading the drain wire.
Q. To date, no steps have been taken to limit stray railway current on wires of the multi-grounded AC distribution system. The condition is recognized and steps may be required in the future. This condition appears to be most noticeable where the AC distribution system and railway DC supply are closely associated in the same building or adjacent buildings.
R. The company does not use the common neutral system except on some rural feeders. On AC network no practical method of limiting the flow of stray current either on primary or secondary phase wires has been found. Until recently it has not been necessary to give this problem serious consideration.
D, E, F, K, M, N, T—None.
G, H, J, P—No reply.

Section B—Drainage to Railway Substations and Booster Drainage

Booster Drainage

To simplify answers to these questions, booster drainage has been divided into two classifications:

Question A
What is the greatest length of drain wire used in your booster drainage installations?
1. Booster drainage from cable sheaths to live rails.
2. Booster drainage from cable sheaths to the negative bus of a railway substation.

Company

C. 2. Have one installation of a selenium rectifier between the cable sheath and the negative bus of a railway substation. The following answers pertain to this installation. Length of the drain cable in the booster drainage installation is approximately 1000 feet.
E. 2. Approximately 2000 feet.
F. No booster drainage on cable to rail drainage circuits, or cable-to-negative cable drainage circuits is used. The only booster drainage tie in existence in Cleveland is from cable to cable. The following answer is with reference to this
1. About ¼ mile.
I. This company has no booster drainage from cable sheaths direct to the negative bus of a railway substation and only one to a railway elevated structure.
All other rectifier installations are pole mounted and connected to the secondary neutral of the system.
1. The greatest length of drain wire used in booster drainage installations is 14 feet from sheaths to the elevated structure of the street railway. One forced drain to secondary neutral is 50 feet long.
L. 1. 0.39-mile.
2. 4.3 miles.
N. 1. One installation about 20 feet.
2. None.
O. 1. No booster drainage to live rails.
2. Approximately 2000 feet.
Q. 1. The company does not at present use booster drainage from cables to either live rails or negative bus at railway substation. Two small forced drainage set-ups are operated between cable sheaths and grounds other than the railway system.
R. 1. 5540 feet.
2. 2850 feet.
T. 1. Average is about 40 feet.
2. None.
A, B, D, K, M—None.
G, H, J, P, S—No reply.

Question B
Booster Drainage—In the underground portion of your booster drain wires what type of insulation is used, if any?
1. Booster drainage from cable sheaths to live rails.
2. Booster drainage from cable sheaths to the negative bus of a railway substation.

Company

C. 2. The drain circuit is entirely underground and is composed of 500 MCM rubber insulated lead sheath cable.
E. 2. No reply.
F. 1. All in the air.
I. 1. Rubber and braid or weatherproof wire is used on these forced drains.
L. 1. Paper insulated, lead covered.
2. Paper insulated, lead covered.
N. 1. Lead covered paper insulated cable in a fibre duct encased in concrete. On future jobs a synthetic rubber cable with neoprene jacket will be used.
2. None.
O. 2. Lead covered rubber insulated wire is used.
R. 1. Lead Sheath cable.
2. Lead Sheath cable.
T. 1. Rubber insulated cable laid in iron pipe or troughing.
2. None.
A, B, D, G, H, J, K, M, P, Q, S—No reply.

Question C
Booster Drainage—What is the highest DC booster voltage used by your company?
1. Booster drainage from cable sheath to live rails, at what amperage?
2. Booster drainage from cable sheaths to the negative bus of a railway substation, at what amperage?

Company

C. 2. The booster voltage is 2 volts at 15 amperes.
E. 2. Approximately 18 volts, 23 amperes.
F. 1. Open circuit 8.5 V—Closed circuit 7.23 V with 2.25 amp. current.
I. 1. The highest rectifier voltage used is 25 volts at 2 amp.
L. 50 volts. 1.35 amperes—50 volts.
2. 55 amperes—6.0 volts.
N. 1. 10 volts at 25 amperes.
2. None.
O. 2. 12 volts DC booster at 30 amperes.
R. 1. 60 volts at 60 amperes.
2. 40 volts at 100 amperes.
T. 1. 30 volts.
2. None.
A, B, D, G, H, J, K, M, P, Q, S—No reply.

Question D
Booster Drainage—What is the highest DC booster amperage used by your company?
1. Booster drainage from cable sheath to live rails, at what voltage?
2. Booster drainage from cable sheaths to the negative bus of a railway substation, at what voltage?

Company

C. 2. The booster current is 15 amperes at 2 volts.
E. 2. Approximately 23 amperes, 18 volts.
F. 1. 10 amperes with 20 volt closed circuit to be installed shortly.
I. 2. The highest forced current used is 400 amperes at 2 volts.
L. 110 amperes. 1. 5.3 volts and 110 amperes. 2. 6.0 volts and 55 amps.
N. 1. 25 amperes at 10 volts.
2. None.
O. 2. The highest DC rectifier used is 30 amperes at 30 volts.
R. 1. 117 amperes at 14 volts.
2. 100 amperes at 40 volts.
T. 1. Average 2-5 amps.
2. None.
A, B, D, G, H, J, K, M, P, Q, S—No reply.

Question E
Booster Drainage—Do you provide any means of protecting the public, the railway company personnel, or your own personnel from shock in event of an open circuit in your drain cable?

Company

C. No steps have been taken to protect personnel from shock in the event of an open circuit in the drain cable. The voltage on the drain cable is less than 10 volts and no protection is considered necessary.
E. Conditions do not require it.
F. Voltage is too low.
I. The possibility of shock because of an open circuit in the drain cable is so remote that no particular means of protection are used.
O. No special protection is used although the drain cable is fused. However, the voltage on these cables are usually under 50 volts DC.
R. Not at present. We are considering the use of a protective device should higher voltage rectifiers be used.
A, B, D, G, H, J, K, M, P, Q, S—No reply.
L, N, T—No.

Question F
Booster Drainage—How does your company protect the rectifiers used in booster drainage connections against surges caused by the failure of power cables?

Company

C. No steps have been taken to protect the rectifier against surges caused by failure of power cables.
E. By the use of fuses.
F. No hazard since power maintenance is excellent.
I. Rectifiers are all protected by adequate fuses.
L. Rectifiers in booster drainage connections not protected against surges caused by failures of power cables.
N. None.
O. The rectifiers are not connected to power company cables but are protected from lightning by arrestors and dunco relays.
R. We have not found it necessary to install protection of this nature.
T. Fuse in AC supply.
A, B, D, G, H, J, K, M, P, Q, S—No reply.

Section C—Reverse Current Switches and Valve Rectifiers

Question A

Can you supply this committee with schematic circuits and data of acceptable automatic switches used to control the direction of currents in drainage bond wires?

Company

B. The telephone company only uses reverse current switches and those in accordance with Bell System Practices.

C. The essential elements of the automatic reverse current switch in use comprise a contactor and a polarized relay. The contactor is operated at 120 volts, AC, and its contacts are rated at 300 amperes, DC. The polarized relay is provided with a high resistance potential winding and a low resistance current winding. The potential winding connected across the switch is energized by the potential difference across the open contacts of the contactor, and closes the 120 volt supply circuit, when the cable sheath potential is 0.5 volt positive with respect to the railway system. When the contactor is closed, sufficient current is shunted through the low resistance winding to hold the relay contacts closed. The polarized relay opens and deenergizes the contactor when the drainage current drops to a predetermined value.

I. The company uses two remotely operated electrolysis AC magnetic switches with three contactors connected in parallel, rated at 100 amp. each and operated by a 230 volt, 25 cycle coil at about .75 amp.

M. We have not developed any special reverse current switches and valve rectifiers.

Q. Five types of switches are used to control reverse current in drain wires. One type is a self actuated electrolysis switch of 100 ampere capacity which operated satisfactorily, within its current capacity, where there was sufficient potential available to actuate the relays and where there was very little or no superimposed AC on the drain wire. Another type is a home made self-actuated polarized switch which is a little less sensitive and with greater inertia of moving parts but which is equipped with a magnetic blow-out to extinguish AC and DC arcs that may be caused by opening of contacts.

Limited experience with this switch shows a lowered contact maintenance when operated in the presence of AC.

A third type switch is actuated by external power. This switch was installed where only low positive potentials were available and, after proper initial adjustments were completed, has operated very satisfactorily. In some locations a simple contactor is used that operates with the DC machine controls, so that it is closed when the machine is on the line and opened when the machine is off. Then there is a manually operated switch, in some drain wires, which are closed or opened depending on the system set up.

S. The switch developed by one company operates on 120 v AC power, has two relays and is used in the protection of lead covered cables. The control relay is a polar type and has two windings and two pairs of contacts. One winding is connected across the fixed contacts of a 350 ampere contactor in series with a 200 watt ballast lamp. When the switch is open, this portion of the circuit has the full voltage between cable and ground impressed on it. The ballast lamp limits the current and protects the relay winding while the cable is negative with respect to the ground, but when the cable becomes positive and reaches a potential in the order of one-quarter volt above ground, the relay operates and closes its contacts. This permits the contact coil to be energized from the AC supply and shunts the lamp to temporarily increase the sensitivity of the control relay.

The magnetic field of the control relay is augmented when current flows in the second winding in parallel with the .001 ohm resistor in the drain circuit. The combined action of the two windings causes the control relay to remain closed as long as current passes from the cable to the ground. When the current decreases to zero and reverses, the control relay opens its contacts interrupting AC power to the contactor and it, in turn, opens its contacts, opening the drainage path.

The switch developed by another company is powered from a 120 v AC service and has three relays. The control is a polar relay having one winding and one pair of contacts. Voltage to actuate the control relay is drawn from the bond wire and is the full voltage between the cable sheath and power ground except for the portion used to drive current through the ballast lamp. When the drain contactor is closed, the ballast lamp is shunted and the current through the control relay varies with current through the drain contacts and heavy duty .005 ohm resistor. An intermediate relay is used to open and close the AC circuit to the coil of the drain relay. Inasmuch as the current necessary to operate the intermediate relay is less than that necessary to operate the drain relay, the polar relay can be more delicately constructed and consequently more sensitive than would be possible otherwise.

The switch used by some companies operates on DC power ordinarily fed through cable wires from a storage battery in the nearest telephone central office. A rectifier is used if the switch is installed too far from a central office to use storage battery power and this rectifier is powered by AC from a local service connection. The switch uses a ballast lamp to protect the control relay from excess currents as is done in the other switches. A filter that by-passes alternating current in the control circuit is also included. Spark suppressors are used to minimize erosion of the intermediate relay contacts, and a capacitor is used to boost the available power when the switch is located a long distance from the supply battery.

The control relay remains in the unoperated condition while the cable is negative with respect to power ground and also until the cable is positive to approximately 0.25 volt. At this voltage the control relay operates to close two battery circuits. One of these includes the drain relay coil, and when this coil is energized, the drain contacts are closed and drainage through the bond takes place. The other circuit includes the hold winding on the control relay. When this circuit is energized, the control relay remains operated until current in the control winding decreases to zero or to some other fixed value near zero. Adjustments are available to set this release in order to secure the desired protection.

Electrolysis switches are mounted where they can be serviced economically or where the length and size of the drainage bond may require. They have been mounted on switch board panels in power stations, on individual panels in other parts of buildings, out-of-doors and in manholes. Thus, the mechanical protection provided for switches extends all the way from none to waterproof boxes capable of keeping all components dry even if the unit is submerged.

Many switches have a nominal drainage current rating of 100 amperes. Others in use are capable of draining as much as 500 amperes. One switch was reported, having a rated current capacity of 2000 amperes.

Dry Rectifiers: Few companies have as yet used dry rectifiers as valves to produce unidirectional current in drainage bonds. Only two installations of the copper oxide type and one of the selenium type have been reported. One of the copper oxide units drains currents in the order of 100 amperes from a 66 KV solid type cable system to ground and has been in use since 1926 with practically no maintenance. Another is rated at 100 amperes with a voltage drop of 0.3 volt at rated current. The selenium unit drains a nominal current of 25 amperes.

T. No.

E, F, H, J, P—No reply.

A, D, G, K, R—No.

L, N, O—Yes.

Question B

What have you found as practical means for powering switches?

Company

B. The telephone company uses 48-volt battery wired from a central office for powering switches.

C. The contactors of the electrolysis switches are powered by 120 volts, 60 cycle, electricity from the distribution mains of the company.

E. Switch is powered by DC central office battery furnished over cable pairs.

F. Commercial power and rectifiers are preferable, older switches are powered by central office battery.

G. Switches used in the past have been powered by bond voltage. If switches are installed in the future, use of an external source of power for operation will be investigated.

I. In general it has been found that electrolysis voltages encountered are too small and too variable to be relied upon to power an electrolysis switch.

L. 120 volt, 60 cycle AC.

N. The company uses only one type of electrolysis reverse current switch. The switch is operated by reverse current and does not require any external power source.

O. Electrolysis switches of the externally operated type are usually powered by central office battery pairs.

S. Power from the drainage circuit, when sufficient; otherwise 120 volts from the substation light and power circuits or distribution secondary system.

A, D, H, J, K, M, P, R, S, T—No reply.

Question C

How much 60 cycle AC (volts) do you find on electrolysis switch control circuits and how do you operate with it?

Company

B. No trouble experienced.

C. No difficulty has been found to result from 60 cycle AC voltage in the sensing circuit of the switch. Presumably these voltages are small and insignificant. On the other hand, 25 cycle potentials frequently found on the rail systems, may cause vibration of the relay armature and false operation. The pole pieces of the polarized relay are provided with heavy damping coils to reduce the vibration.

E. Have not experienced more than about one volt. This does not cause trouble.

F. None.

G. No AC voltage of troublesome magnitude has been detected on electrolysis switches.

I. Have not encountered any 60 cycle current on electrolysis switch control circuits. The largest street switch is a 300 amp. contactor. The largest railway station switch is capable of handling a peak of 2000 amp.

L. 60 cycle, AC potentials have not been troublesome in electrolysis switch control circuits on system.

N. None.

O. Troublesome AC voltage has been eliminated largely by the use of a Speaal switch and the voltages are not known.

Q. The open circuit AC potential in some circuits has been 15 to 20 volts. Where these potentials cause excessive damage to contacts a serious effort was made to set up a stray current situation so that no switch was required, and other methods of control (operate with either solid drain or open drain) or installation of "home made" switch, or contactor operated from DC machine controls were used.

A, D, H, J, K, M, P, R, S, T—No reply.

Question D

What sizes of switches do you find adequate to provide necessary drainage?

Company

B. 100 amp. switches are used by the telephone company.

C. A 300 ampere contactor has been found adequate for most installations.

E. 200 amperes.

F. Most switches are 100 ampere capacity, but are over fused to 200 amperes temporarily. Some 100 ampere switches have been converted to 200 ampere. The new switches which are to be installed will be of 400 ampere capacity.

G. 200 to 400 amperes.

L. 500 ampere capacity reverse current switches have been adequate at locations where installed.

N. Two sizes—250 amp. and 500 amp. capacity.

O. A 200 ampere switch should be large enough for most needs as the amount of current handled is being reduced rather than increased by street car abandonment.

Q. For practically all situations where electrolysis switches are required the 100 ampere capacity has been satisfactory. About one case in ten, where switches are required, a capacity greater than 100 amperes is demanded.

A, D, H, I, J, K, M, P, R, S, T—No reply.

Question E

Can you provide information including technical data and experiences with dry rectifiers for the control of currents in drainage bond wires? Give trick circuits, if any, including patent data.

Company

A. This company has two installations of valve rectifiers to prevent reverse current flow in drainage bond wires, as follows:

a. An oil-filled type copper-oxide rectifier is installed in a drain bond between the 66 KV solid type cable system and a street-railway substation approximately a half-mile away. This drain cable is 1000 MCM paper-and-lead and carries a peak current in excess of 100 amperes. This rectifier has been in operation since about 1926 with practically no maintenance.

b. A selenium-stack dry-type rectifier is installed in a drain cable between a 66 KV oil-filled lead-sheathed cable line and a group of 13.2 KV lead-sheathed cables at a transverse crossing of the two systems. This drain cable is a 500 MCM low-voltage-rubber-insulated cable approximately 50 feet long and is installed in a duct. The rectifier was sealed into a lead sleeve and mounted on the manhole wall. Introduction of this rectifier reduced the peak drainage from about 50 to about 25 amperes.

I. Rectifiers used by this company are of the copper oxide or selenium battery charger type available from most appliance manufacturers. Current is controlled by a variac in the input side or by proper size resistors. A 115 volt AC input is wired through a switch to a variac or resistor combination to the input of the rectifier. The negative terminal of the rectifier is then connected to the cable sheaths. No trick circuits are used.

L. Experience with dry rectifiers for control of currents in drainage bond wires has been limited and at present no trick circuits are used.

M. Have provided dry rectifiers in the form of carbon electrodes inserted in the earth and connected to lead sheath cables to offer a counter EMF to local cell action in a slag dump area at the south edge of Salem, Ohio.

Q. No actual experience has been had in the use of dry rectifiers for the control of current in drain wires. Their use has been given theoretical consideration but in each case the rectifier characteristics did not fit the service requirements. R Copper oxide stacks have been used to prevent current reversals on drain and bond wires. They have been very effective in shipyards in controlling stray welding currents.

In one case where a copper oxide stack was used to prevent current reversals in a bond between cable sheaths and the street car rails it was found that excessive back voltage damaged the copper oxide plates. This condition was overcome by the use of a relay which, when the back voltage exceeded a certain value, opened the circuit through the copper oxide valve and inserted a resistor in the bond wire which served to limit the reverse flow of current. When the back voltage dropped to a low value the relay took the resistor out of the circuit and put the valve back into the bond wire circuit.

B, C, E, F, G, N, O—No.

D, H, J, K, P, S, T—No reply.

Publication No. 57-2

Effect of Hot Hydrogen Sulfide Environments on Various Metals*

A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry from Sinclair Research Laboratories, Inc., Harvey, Ill.*

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Abstract

Sinclair platinum catalyst reformers and desulfurizers designed on corrosion rate data taken from literature and laboratory tests had low corrosion rates. However, scaling as a result of high temperature sulfide attack caused clogging and pressure drop.

Plant and bench scale corrosion tests were made using specimens of various steels and alloys directly in catalyst beds. These tests showed that at hydrogen sulfide concentrations considered low only 18-8 stainless steel exhibited sufficient resistance for long time service. Test apparatus is described, procedure outlined and corrosion rates reported on tests made.

Examples of scale formation are shown, constituents analyzed and explanation of scale phenomena offered.

Tests resulted in decisions concerning additional equipment and pointed to certain alloys as desirable for service expected. Refinery corrosion tests of alloy steels and aluminum coated carbon steels were made and corrosion rates plotted, indicating that low chromium steels are satisfactory provided the hydrogen sulfide-hydrogen ratio is lower than 100 ppm. Aluminum coated steels proved to have marked resistance to attack with best results achieved with calorized coatings.

Conclusions on proper material selection related to hydrogen sulfide concentration are given. **3.2.2**

Introduction

SINCLAIR operates three fixed-bed reforming units using Sinclair-Baker RD-150 platinum catalyst for upgrading naphtha feed stocks to high octane gasoline. In addition, two catalytic desulfurizers using a cobalt-molybdenum catalyst are operated for hydrogen removal of sulfur from naphthas and cycle oil. These units have a common problem involving high temperature hydrogen sulfide environments and attendant clogging of equipment by dislodged iron sulfide scale.

The first Sinclair catalytic reformer was put on stream in October 1954 at Marcus Hook, Pennsylvania. The second unit came on stream at East Chicago, Indiana in March 1955. The third reforming unit was started up in March 1956 at Houston, Texas. These units utilize fixed catalyst beds with interheaters and operate at 500 psi with maximum stream temperatures near 950 F. All except the Houston unit have amine systems to scrub hydrogen sulfide from the recycle gases. A simplified flow diagram for the Marcus Hook Unit which is also representative of the East Chicago Unit is shown in Figure 1. In the Houston unit a cobalt-molybdenum desulfurizer precedes the reformer so that the naphtha feed to the reformer is free of sulfur.

In addition to the reforming units Sinclair operates two catalytic hydrodesulfurization units where hot hydrogen sulfide must be handled. The first unit, at Marcus Hook, came on stream in December 1955, the second (a section of the Houston reformer) was started in March 1956. These hydrodesulfurization units operate at temperatures of around 750 F. A flow diagram of the Marcus Hook unit is presented in Figure 2.

Operating experience with these units has been relatively good from a corrosion standpoint. Most difficulty occurred in the Marcus Hook unit where the original mill scale in the unit flaked off. This, together with sulfide formed during processing, caused excessive pressure drop in the first reactor and early termination of the first run after four months' operation. The first reactor was converted from down flow to radial flow and the unit was put back on stream without removing the original catalyst charge. When sulfide scale plugging of the second reactor became the bottleneck it also was converted to radial flow about a year later.

In the other units the combination of desulfurization, recycle gas treating and radial flow reactors have practically eliminated hydrogen sulfide corrosion-caused operational difficulties.

Pilot Plant and Bench Scale Corrosion

Prior to the design of any of these units, bench scale and pilot plant corrosion studies were made.

★ Presented at a meeting of South Central Region, National Association of Corrosion Engineers, San Antonio, Texas, October 23-26, 1956.

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Specimens of various steels and alloys were exposed directly in catalyst beds of laboratory reactors under processing conditions. Advantages of this method lie in relatively long time exposure, close approach to commercial conditions and convenience. Inability to manipulate process conditions to examine corrosion variables is the chief disadvantage. Useful data, such as the corrosion rates shown in Figure 3, were derived. Figure 3 indicates corrosion rates obtained by weight loss measurements after specimens were exposed to various bench scale hydrodesulfurizing runs.

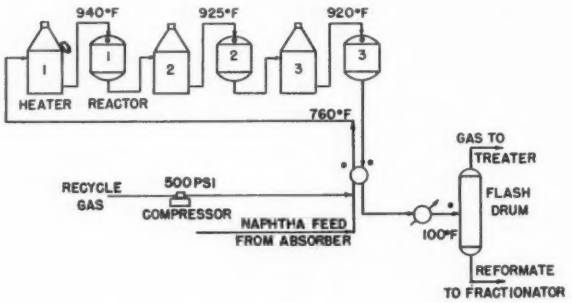


Figure 1—Flow diagram Sinclair Marcus Hook reformer, showing location of corrosion test spools—0.

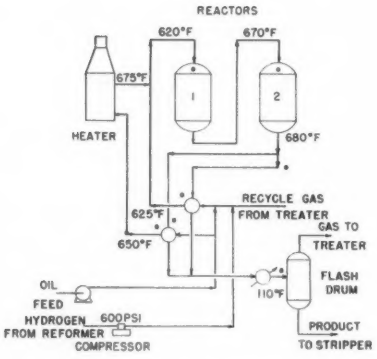


Figure 2—Flow diagram Sinclair Marcus Hook hydrodesulfurization unit showing location of corrosion test spools—0.

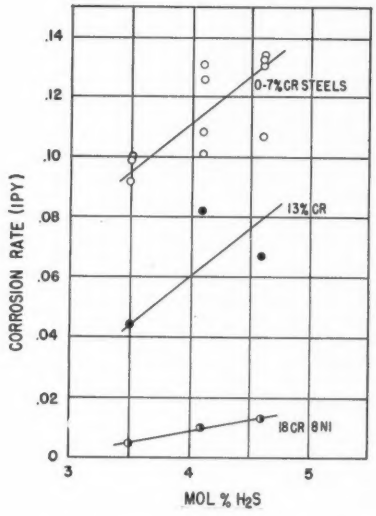


Figure 3—Corrosion rates of various steels in laboratory HDS unit, 760 F, 450 psi, 200 hours.

TABLE 1—Composition of Steels Used in Hydrogen Sulfide Tests

Code	Material	C	Mn	P	S	Si	Cr	Ni	Mo	Cb
A	Carbon Steel	.20	.70	.012	.02	.009	.....	.....	.....	.....
AE	Carbon ½ Mo	.13	.54	.038	.02	.25	.....	.....	.54	.....
B	1¼ Cr-½ Mo	.17	.51	.011	.01	.68	1.13	.086	.23	.....
C	4-6 Cr-½ Mo	.16	.43	.014	.009	.42	4.57	.084	.19	.....
D	6-8 Cr-½ Mo	.13	.52	.025	.007	.85	6.18	.12	.27	.....
E	13 Cr (410)	.12	.49	.015	.016	.44	13.28	.32	Tr	.....
AD	17 Cr (430)	.11	.435	.01	.009	.40	16.60	.....	.....	0
F	18-8 (304)	.13	.46	.040	.024	.39	18.36	8.68	.16	.....
X	18-8 (304L)	.015	1.32	.024	.010	.46	18.44	9.70	.....	.....
Y	18-8 (316L)	.021	1.15	.022	.012	.50	17.16	12.77	2.38	.....
Z	18-8 (347)	.26	1.61	.02	.05	.52	18.90	11.00	.....	.927

Cal	Aluminum coated carbon steel ("calorized")
Al Dip	Aluminum coated carbon steel (hot dipped)
Al Dif	Aluminum coated carbon steel (hot dipped and diffused)
Cal C	Calorized 4-6 Cr-½ Mo
Al Dif C	Aluminum dipped and diffused 4-6 Cr-½ Mo.

The data are for once-through, non-treated recycle gas operation.

On the basis of these corrosion tests it became apparent that even at concentrations of hydrogen sulfide hitherto considered low (i.e., 4 mol %) of the alloys tested, only 18-8 stainless steel had low enough corrosion rates (less than .05 ipy) for long time service. The tests also indicated that lowering hydrogen-sulfide content would reduce corrosion. Little difference in corrosion rates in the 0-6% chromium range was noted.

A literature survey yielded little corrosion data at the low hydrogen sulfide concentrations which would be encountered in commercial desulfurization and reforming. Work by Dittrich,[1,2] White and Marek,[3] and Ballabio and Paztonesi[4] was mainly at hydrogen sulfide concentrations of over 2 vol. percent. It became evident, on the basis of such data, that for a commercial unit high alloys would be needed unless the hydrogen sulfide concentrations could be lowered to even smaller concentrations. At this point it was decided to install amine gas treaters on the Marcus Hook desulfurizer and reformer.

Special Laboratory H_2S Studies

Test Apparatus

To further investigate the corrosion rates as a function of decreasing hydrogen sulfide concentration, test reactors were set up where specimens of various steels could be exposed to varying hydrogen sulfide and hydrogen concentrations. Weighed and measured disc-shaped specimens of various alloy and aluminum coated steels, approximately ¾-inch in diameter and 1/16-inch thick (about 6 cm² total surface area) were placed in weighed 0000 tall-form porcelain crucibles held vertically in an aluminum rack which was introduced into the reactor. The scale formed was recovered for analysis and weight gain measurements were made. Analysis of steels tested are reported in Table 1.

Gas Blends

Considerable difficulty was experienced in preparing hydrogen sulfide-hydrogen blends because of the great difference in the density of the gases. Periodic dilution of a blend made richer than desired proved to be the most successful method. For example, a 6% hydrogen sulfide blend made by adding hydrogen sulfide through the top communicating valve of a double-valved steel cylinder would be diluted by introducing hydrogen through the valve opening to the bottom of the cylinder. The mixture would then

be warmed with heat lamps for several days. After the mixture stabilized, as shown by chemical analysis, a run could be made. After the run the mixture would be diluted by further hydrogen addition to lower concentrations for further runs after an aging period.

Test Procedure

Although it was realized that, in a scaling process, short exposure times can result in excessive corrosion rates, a test period of 100 hours was selected as being the most practical. According to Backensto[5] after 100 hours the corrosion rate vs time curve had constant slope. The specimen rack was sealed in the reactor which was purged before and after the hydrogen sulfide exposure with pre-purified nitrogen. Tests were conducted at 500 psi. This is representative of Sinclair reformer operating pressures. Most of the study was made at two temperature levels, 750 and 950 F for the same reasons.

Samples of the flowing gas were taken periodically and analyzed by mass spectrometer when the hydrogen sulfide exceeded 0.5%, and by gravimetric means at lower concentrations. Over the course of the 100-hour period agreement was found in successive analysis on most tests. Volumes of effluent gases were measured by means of a wet test meter after the hydrogen sulfide was removed by scrubbing by a cadmium chloride solution. Analysis of the cadmium chloride solution gave the average effluent hydrogen sulfide concentration.

At the end of the test period the sample crucibles were removed from the purged and cooled reactor and reweighed. Typical appearance of the specimens at the end of a test can be seen in Figure 4. The increase in weight, due to sulfidation, can be used to calculate the corrosion rate, assuming only iron sulfide is formed. However, in addition to this method the specimens are descaled in warm inhibited 50% hydrochloric acid and the weight loss measured. As an internal check on the accuracy of weighing and efficiency of scale removal the weight gain (sulfur) can be compared to the weight lost (iron). The ratio is .574 for iron sulfide which was the relationship observed in most cases. However, in the case of alloys higher than 13% chromium this ratio does not hold because of the inclusion of chromium in the scale.

Observed Laboratory Corrosion Rates

On the basis of the weight changes, the corrosion rate, expressed as inches per year, was calculated. The corrosion rates obtained from laboratory tests over a wide range of hydrogen sulfide-hydrogen concentrations and at temperatures of 750 F and 950 F are plotted in Figures 5 and 6. Not plotted are the results on three types of aluminum coated carbon steel, all of which had nil corrosion rates even at the 12 mol percent hydrogen sulfide conditions. Several interesting conclusions can be drawn from these curves. As would be expected, hydrogen sulfide attack is generally more severe at 950 F than at 750 F, particularly in the lower alloy steels and in the 13 chromium and 18-8 steels at concentrations above about 0.3 mol percent hydrogen sulfide.

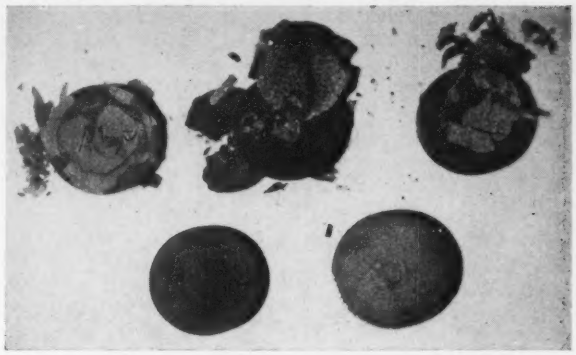


Figure 4—Appearance of steels after exposure to 0.13 Mol % H_2S in H_2 at 750 F, 500 psi, 100-hour test. Top row left to right, carbon steel, 4-6 Cr-½ Mo, 13% Cr. Bottom row left to right, 18-8 (304), calorized carbon steel.

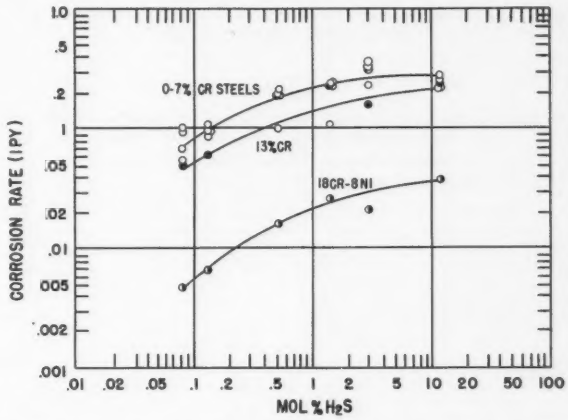


Figure 5—Corrosion rates of various steels in hydrogen sulfide-hydrogen mixtures at 750 F, 500 psi, 100-hour laboratory tests.

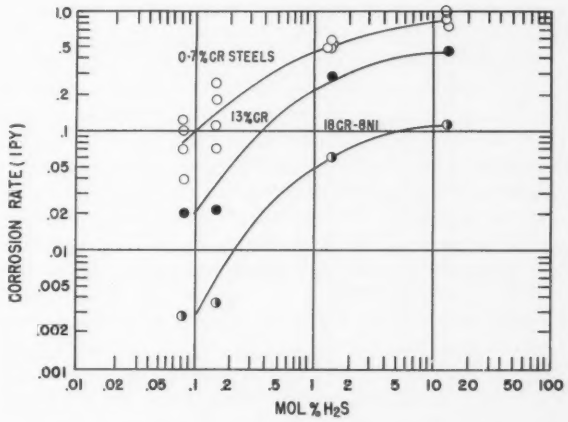


Figure 6—Corrosion rates of various steels in hydrogen sulfide-hydrogen mixtures at 950 F, 500 psi, 100-hour laboratory tests.

Low chromium steels (up to 6% chromium) show no better corrosion resistance than plain carbon steel and in some tests worse. Not until approximately 13% chromium was in the steel was there an appreciable lowering of the scaling rate. Further improvement in hydrogen sulfide resistance can be achieved

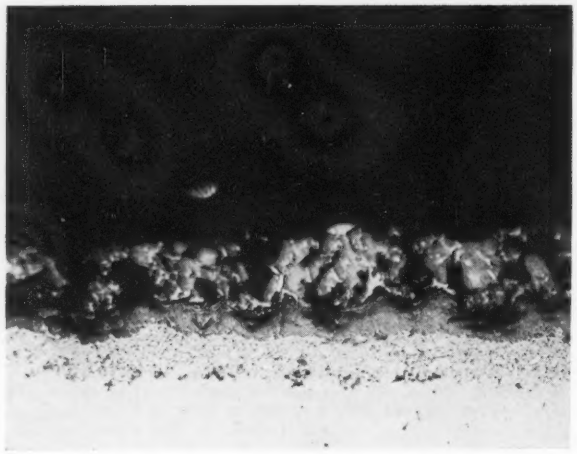


Figure 7—Microstructure of sulfide scale on surface of 4-6% Cr-½ Mo steel. Intergranular penetration of steel is noted. Three layers of sulfide have formed. Unetched. 200X.

TABLE 2
Chemical Analyses of Scale from Steels Exposed to Processing and Regeneration in Houston HDS Unit
(.086 mol % H_2S, 707 F, 250 psi, 1900 hours)

STEEL ANALYSIS	Layer	ANALYSIS OF SCALE WT. PERCENT		
		Percent Cr	Percent Fe	Percent S
Carbon Steel.....	Outer	0	49.8	19.5
	Middle	0	48.5	24.4
	Inner	0	49.4	29.9
4.57 Percent Cr.....	Outer	0	57.2	16.7
	Middle	9.30	45.1	24.1
	Inner	7.66	45.8	18.0
13.28 Percent Cr.....	Outer	0.18	68.5	3.30
	Inner	20.0	36.6	22.8
16.60 Percent Cr.....	Single	8.25	61.1	6.88
18.44 Percent Cr., 9.70 Percent Ni....	Single	10.7	40.1	11.8

by the marginal addition of about 5% chromium as in the 18-8 (304) and 430 (17% chromium) grades.

Also corrosion rates increase with increasing hydrogen sulfide concentrations in all steels with the rate of increase being greater at low concentration than at the higher. Thus, small changes in low concentrations can have more effect on corrosion rates than large changes in high concentrations.

It was concluded from laboratory tests that even at hydrogen sulfide concentrations as low as 0.08 vol. percent the low chromium steels would not be satisfactory and at least 13% chromium steel would be required unless the hydrogen sulfide concentrations were lowered further. It was concluded also that aluminum coated steels could be used to resist even high hydrogen sulfide concentrations. Further information about the long time serviceability of the aluminum coatings was sought.

Scale Formation

Gel'd and Esin[6] describe the sulfide layers which form on a steel in high sulfur atmospheres in the roasting of sulfide ores as two: an interior layer, close in composition to pyrrhotite and an exterior layer approaching pyrites (FeS_2) in composition. The interior layer also can be divided into two sub-layers reproducing the original surface of the metallic specimen.

Also, in his tests on corrosion of iron by molten sulfur, Dravnieks[7] reported a three layered scale, with the outer layer being pyrite (which showed ferromagnetism apparently due to the presence of some pyrrhotite), the middle layer: magnetic pyrrhotite, and a thin powdery layer close to the steel which was non-magnetic, of FeS to $FeS_{1.15}$ composition (troilite).

During the course of laboratory corrosion tests the formation of a similar three-layered scale was noted also. In commercial operation, scale of several separate layers often forms. The number of layers corresponds to the number of major changes in operating conditions. What is being referred to here and what has been repeatedly observed where temperature and/or hydrogen sulfide concentration is sufficiently high, is the formation of three distinct scale layers in a single exposure at constant pressure, temperature and hydrogen sulfide concentration.

A good example of this is noted in Figure 4. In the 4-6 chromium specimen C-19 (second from left, top row) the very loose flaky outer layer can be seen detached from the metal. Typically this outer layer is weak, course-grained, has a metallic luster and generally is non-magnetic or only partially magnetic. Theoretically, as described by Haraldsen in **Structure Reports**[8] and Huckel[9] this non-magnetic phase should be either paramagnetic troilite: FeS to $FeS_{1.10}$, or pyrites, FeS_2 or possibly a mixture of the two. However, at the low hydrogen sulfide/hydrogen ratios in the tests reported here, pyrites are not stable and are not observed. X-ray diffraction analysis of these non-magnetic outer layers reveals FeS, often together with the super lattice FeS structure (α) which has a variable composition: from 50 to 50.74 atomic percent sulfur. Also, chemical analysis of typical outer layers generally shows only a slight excess of sulfur over the stoichiometric amount, i.e., on the order of 0.1 to 0.7 weight percent. This evidence suggests that the outer layer is paramagnetic troilite containing an excess of sulfur.

The black, dense middle layer and the third layer, the thin film which is found directly on the iron generally show ferromagnetic properties and although β-pyrrhotite (52.38 to 53.4 atomic percent sulfur) is ferromagnetic, chemical analyses of the middle layers always have shown less sulfur than this composition. Also, the super-lattice form of FeS often is found in this middle layer. The greater density observed also indicates a lower sulfur content than the loose outer layer. It is felt, therefore, that these inner layers are also troilite, but with excess iron in solid solution (up to 7% is possible) which accounts for their ferromagnetic properties.

The microstructure of this triple layer formation is shown in Figure 7.

The triple layer occurrence persists in the chromium containing steels. The middle layer becomes harder and more tightly adherent with increasing chromium, though it is still generally ferromagnetic. The outer layer has similar properties to that formed on iron and carbon steel. Both layers decrease in

thickness with increasing chromium in the steel. Chemical analysis confirms Dittrich's[2] observation that the intermediate layer is greatly enriched in chromium, containing roughly twice the chromium content of the base steel, whereas the loose, flakey, outer layer has far less chromium than the base metal, often less than 10% of the base metal concentration. Chromium concentrates in the middle layer, and sometimes the spinel-like structure $FeCr_2S_4$ is observed in the high chromium steels. Concentration of chromium in the middle layer apparently acts as a diffusion barrier for Fe ions, the critical amount for appreciable reduction in corrosion rate being on the order of 20-30 weight percent (corresponding to a chromium/iron atomic ratio in the middle scale layer of about 0.6 to 1.1), which occurs in the 13% chromium steel. Analyses to illustrate this are given in Table 2.

Refinery Metallurgy

On the basis of the laboratory tests and the reported investigation of Backensto[5] it was decided to equip the first Sinclair catalytic reforming unit at Marcus Hook with a glycol amine scrubbing system to remove hydrogen sulfide from the recycle gas in an effort to keep the hydrogen-sulfide content in the unit below 100 ppm, mol basis. Metallurgy for this unit was based on the necessity of avoiding high temperature hydrogen attack as well as hydrogen sulfide corrosion. At the conditions of operation 950-1050 F and 500 psi with about 80 mol percent hydrogen the curves of Nelson[10] show that at the minimum of steel of 1% chromium and ½% molybdenum is required to resist the decarburizing and cracking effects of high temperature hydrogen.

Thus for the heater tubes, return bends, transfer piping, exchanger shells and reactor internals on the Marcus Hook unit, 4-6% Cr-1/2 Mo Steel was used. The three reactors were carbon steel with refractory liners.

For the duplicate unit at East Chicago on stream in March 1955 the same alloys were used.

As more and more information became certain about the hydrogen sulfide corrosion problem the choice of alloys was more precise, thus in the Houston catalytic reformer which came on stream in March 1956, 4-6% Cr-1/2 Mo heater tubes were selected but transfer piping was 1% Cr-1/2 Mo. The reactor internals were 13% Cr (either 405 or 410) and 18-8 (304, 321 or 347).

The two catalytic desulfurizers operate at lower temperatures than the reformers (i.e. 750 compared to 950 F), but at higher hydrogen sulfide concentrations. In the Marcus Hook light cycle oil hydrodesulfurization unit heater tubes are 4-6% Cr-½ Mo, while transfer piping is 13 Cr in the hottest sections. Exchanger shells are 12 Cr clad carbon steel (410 on 212B). The reactors are 316-lined carbon moly steel.

In the Houston desulfurizer section of the reformer, heater tubes are 4-6% Cr-½ Mo and transfer piping carbon-½ Mo steels.

Refinery Corrosion Tests

To continue the study of the hydrogen sulfide corrosion problem test specimens of various alloy steels and aluminum coated carbon steels were made up and installed in various locations of each unit as it was being constructed. A standard test specimen 1½-inch dia. x 1/16-inch thick with a .368-inch dia. central hole was adopted. These were finished on 120 grit, measured, degreased in acetone and weighed. Spools of several of these specimens supported on a ceramic covered 25 Cr-20 Ni rod were made up. End brackets supporting these spools were tack welded to the inside surfaces of piping where they would be exposed directly to the process stream. Exposure times ranged from 1500 to nearly 8000 hours. The location of corrosion specimens in the units is shown in Figures 1 and 2.

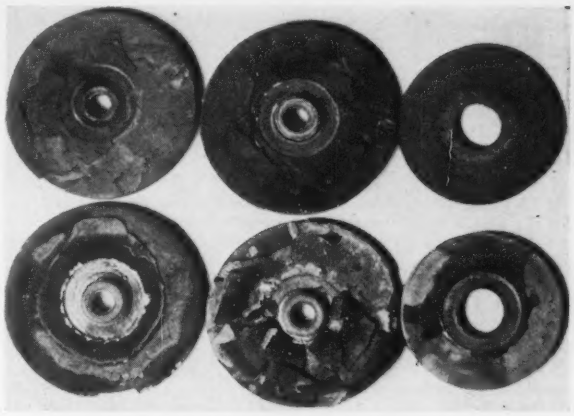


Figure 8—Corrosion specimens from reactor inlet Marcus Hook HDS Unit, 630 F, 0.126 Mol % H_2S, 500 psi, 4112 hours.

Figure 8 shows six specimens after 4112 hours' exposure in the reactor inlet stream at the Marcus Hook hydrodesulfurization unit. The flaky scale is typical of hydrogen sulfide attack. This specimen set, in addition to exposure to processing conditions, also has been subject to regeneration conditions, therefore some of the scale has been converted to oxide.

Cleaning of Corrosion Specimens

Corrosion specimens were removed during turnarounds, samples of scale taken for analysis and the remainder cleaned by chemical methods. Several cleaning techniques were tried. Where part of the sulfide scale has been converted to oxide, immersion of the scaled specimen in a 900 F sodium hydroxidesodium hydride bath followed by a water quench and warm inhibited 50% hydrochloric acid immersion was found to be the easiest method. The scale is removed from the low alloys very readily; longer soaking times with steel wool-soap scrubbing is required in the case of the high chromium steels. Where the scale had not been oxidized (as in the case of the laboratory tests) the molten caustic bath immersion could be dispensed with. Metal loss on blanks due to this cleaning technique was low as noted in Table 3 and varied between about 0.4 to 3.0 mg/cm².

Cleaning of the aluminum coated steels was accomplished by wire brushing and acetone degreasing

because they are attacked by hydrochloric acid and hot caustic.

From weight losses of these corrosion specimens the corrosion rates in the various sections of the units were calculated. These data divide into two groups: 1) corrosion rates in catalytic reformers and 2) corrosion rates in hydrodesulfurization units. Range in results is in Table 4 and the averages plotted in Figures 9 and 10.

TABLE 3
Chemical Analyses of Sulfide Scales Formed on Various Steels in a Commercial Catalytic Reforming Unit

STEEL	Layer	ANALYSIS OF SCALE	
		Percent Cr	Percent Fe
Carbon Steel	Outer	0	70.8
	Middle	0	68.7
1.13 Percent Cr	Outer	1.61	65 2
	Middle	1.83	63.2
4.57 Percent Cr	Outer	4.64	56.9
	Middle	6.88	55.2
6.18 Percent Cr	Outer	5.74	55.2
	Middle	9.88	50.7
13.28 Percent Cr	Outer	3.60	62.7
	Middle	22.3	....
18.36 Percent Cr, 8.68 Percent Ni	Single	9.2	....

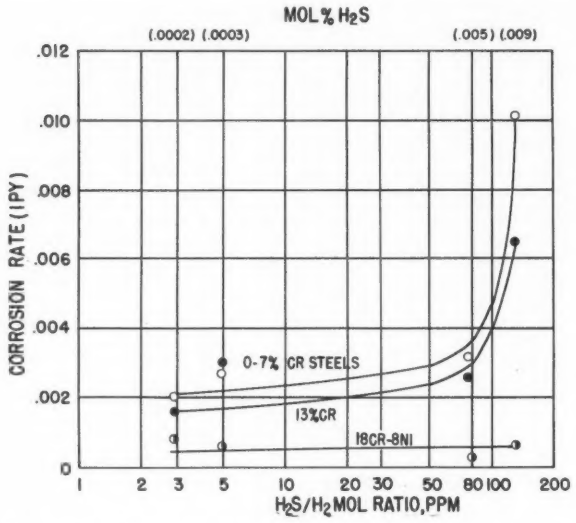


Figure 9—Catalytic reformer average corrosion rates at 925 F, average 500 psi.

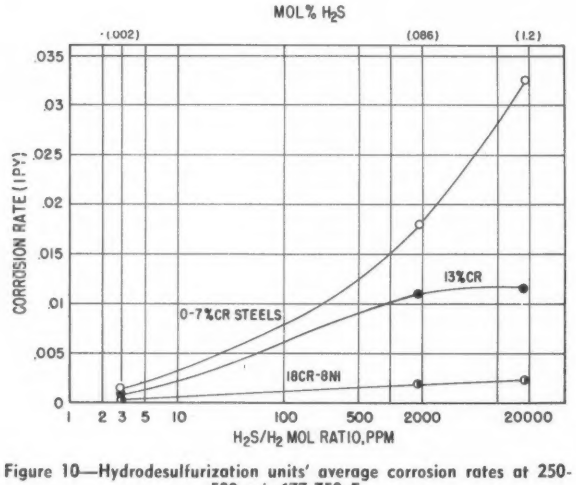


Figure 10—Hydrodesulfurization units' average corrosion rates at 250-500 psi, 677-750 F.

Temperatures are higher in the reformers but the sulfur contents higher in the desulfurizers. Within the same unit there will be a difference in corrosion rates because of location, thus the corrosion usually is less ahead of the first reactor, because the organic sulfur compounds in the feed are not as corrosive as the hydrogen sulfide to which they are converted in the first catalyst bed.

Corrosion rates were plotted as a function of the hydrogen sulfide-hydrogen ratio because as shown by Rosenqvist[11] formation of sulfides of iron is a function of this ratio and also because use of this ratio permitted corrosion rate comparisons where the amount of hydrogen was a variable.

Generally the metal loss in the reformers was found to be small, although even at the relatively low corrosion rates shown in Figure 9 considerable difficulty with increasing pressure drop due to scale in the reactors at Marcus Hook led to the change in the design of the first two reactors from downflow to radial flow. This same consideration caused the first three reactors in the Houston Reformer to be radial flow.

Catalyst is regenerated at minimum intervals of about six months, to maximums of one year, so sulfide scale is not removed very often.

With regard to reformer corrosion rates it is seen in Figure 9 that there is very little corrosion even of carbon and low chromium steels at H_2S/H_2 ratios below 100 ppm. Above this the corrosion rate becomes relatively much higher. These data are from the Marcus Hook Unit where the greatest difficulty has been experienced. Sinclair currently is using a figure of 100 ppm H_2S/H_2 ratio as a maximum design figure. Because no laboratory corrosion tests have been made at these low concentrations a comparison of laboratory and plant data for the reformers is impossible.

Desulfurizer corrosion rates are shown in Figure

TABLE 4
Weight Loss of Blank Corrosion Specimens Due to 900 F NaOH-NaH then 150 F 6N HCl Cleaning

Treatment;
1) Immersion in 900 F NaOH-NaH bath for 10 min.
2) Quenched in cold water.
3) Washed in hot water.
4) Immersed in 150 F 6N HCl + 6cc Rodine 50 inhibitor for 3 minutes.
5) Washed in hot H_2O, dried in acetone and weighed.

Material	Metal Loss gr/cm²
Carbon Steel	.00185
1¼ Percent Cr-½ Mo	.000575
4-6 Cr-½ Mo	.00286
6-8 Cr-½ Mo	.0023
18-8 (316)	.0005
18-8 (304L)	.00163
18-8 (316L)	.00185
17 Cr (430)	.00228
Inconel	.00041
25 Cr-12 Ni (309)	.00129
Carbon-½ Mo	.0012
25 Cr-20 Ni (310)	.00124
17 Cr-7 Mn (201)	.00184

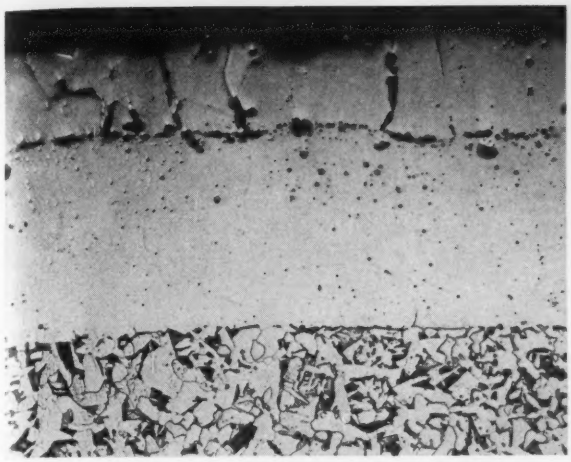


Figure 11—As-received calorized coating. Nital. 100X.

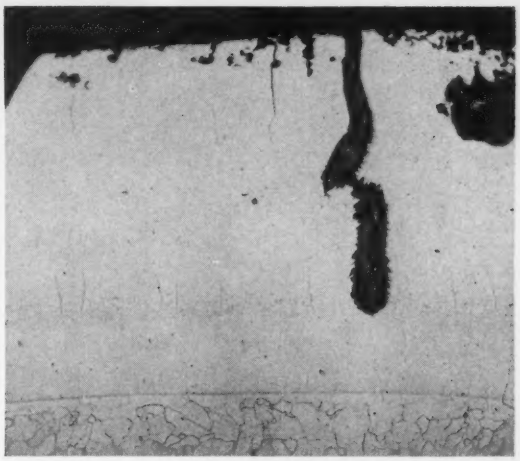


Figure 12—As-exposed calorized coating. East Chicago No. 1 Reactor inlet, .0002 Mol % H_2S, 910-933 F, 500 psi, 9190 hours. Nital. 100X.

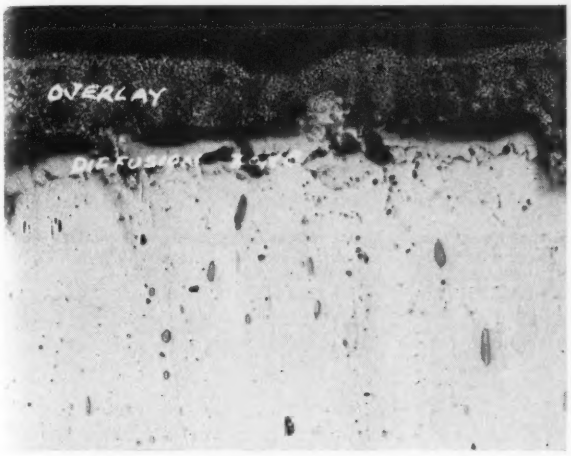


Figure 13—As-received aluminum dipped. Unetched. 100X.

10. Again, as the H_2S/H_2 ratio increases above about 100 the corrosion rates become higher. Stainless 18-8 shows very low corrosion rates in all units, 13% Cr steel is intermediate between the 18-8 grades and the low chromium steels. The long time corrosion rates observed in these desulfurizers is much lower than would be predicted by the short-time laboratory tests, illustrating a deficiency in laboratory corrosion testing. As indicated by scale thickness measurements the corrosion rates on the piping, heater tubing, etc. is well represented by the corrosion test spool measurements. Maximum scale thickness in the units has been on the order of 0.10-inch in the Marcus Hook desulfurizer, (Figure 8) compared to about .015-inch at East Chicago, on 4-6% Cr steels. Calorizing of transfer lines on the Marcus Hook

TABLE 5—Corrosion Rates in Commercial Units

LOCATION	CONDITIONS OF EXPOSURE								Observed Corrosion Rates (Range, IPY)		
						Calculated Conditions at Point of Exposure					
	Weight % S in Feed (Avg.)	H_2S in Recycle Gas Mol ppm (Avg.)	Average °F	psi	Hours Exposure	H_2S Mol ppm	H_2 Mol %	$\frac{H_2S}{H_2}$ Ratio ($\times 10^6$)	0-6% Cr	13% Cr	18 Cr-8 Ni Grades
CATALYTIC REFORMERS											
East Chicago	**.012**	**39**									
Ahead of 1st reactor	....	....	922	500	9190	2	69.5	2.9	.002	.0016	.0008
Ahead of 1st reactor[1]	....	....	750	500	9190	2	69.5	2.9	.001-.002	.0008	.0003
Downstream of 1st reactor	....	....	910	500	9190	54	69.5	78	.003-.004	.002-.002	.0002-.0003
Marcus Hook	**.021**	**91**									
Ahead of 1st reactor	....	....	940	500	5088	3.34	68.0	4.9	.002-.003	.003	.0005-.0007
Downstream of 1st reactor	....	....	920	500	5088 8162	89 89	68.0 68.0	131 131	.009-.015 .007-.011	.007-.008 .005	.0005 .005
HYDRODESULFURIZERS											
Marcus Hook	**1.33**	**1000**									
Ahead of reactor[2]	....	....	628	500	1502	1260	65.0	1940	.010-.012	.0035	.0006
Reactor effluent	....	....	677	500	1502	12000	65.0	18600	.031-.034	.011-.012	.0022-.0025
Houston	**.053**	....	707	250	1900	860	47	1830	.017-.019	.011	.002

[1] These results plotted on Figure 10.
[2] Not plotted because of low temperature.

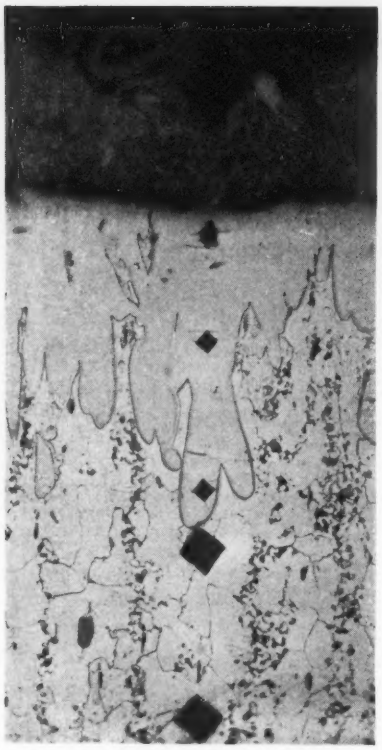


Figure 14—As-exposed aluminum dipped carbon steel. 1502 hours, 1.2 Mol % H_2S at 672-683 F, 500 psi. Aluminum overlayer .004-inch diffusion zone .003-.009-inch. Diamond pyramid hardness, right to left: overlayer 43 DPH, 762, 772, 673, 168, 151. Nital etch. 200X.

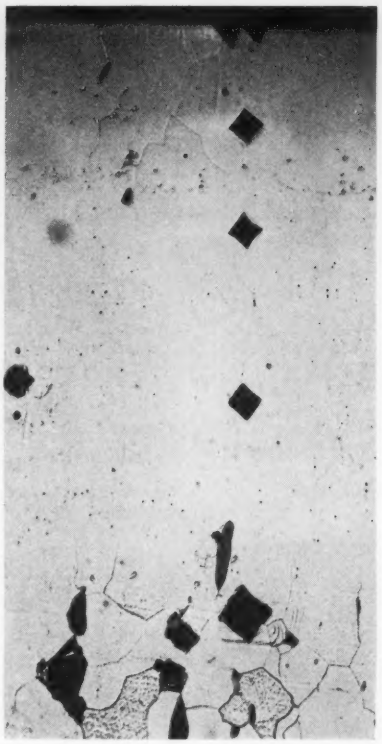


Figure 15—As-exposed aluminum dipped and diffused coating. After same exposure as Figure 13. Overlayer (not visible): .003-.005-inch. Fe-Al diffusion zone .005-.009-inch. DPH (R to L) 907, 933, 397, 136, 160. Nital etch. 200X.

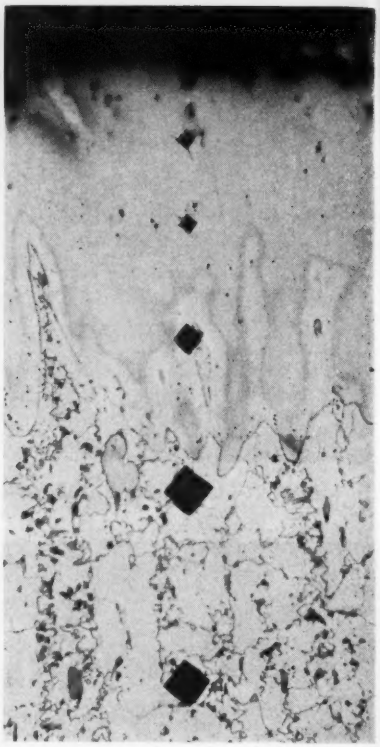


Figure 16—As-exposed calorized coating. Same exposure Figure 14. Overlayer .004-inch thick. Inner Zone .012-inch thick. DPH (R to L) 287, 285, 287, 118. Nital etch. 200X

HDS unit will eleminate excessive scaling when completed.

In summary, on the basis of plant corrosion testing it is indicated that low chromium steels can be used satisfactorily provided that the hydrogen sulfide-hydrogen ratio is lower than 100 ppm.

Aluminum Coated Steels

Several types of aluminum-coated steels were exposed on plant corrosion test spools throughout the various units. Laboratory tests had indicated that all of the various types of aluminum coatings provided protection against hydrogen sulfide attack, even for carbon steel. Plant exposures were made to ascertain the long run serviceability of the coatings.

Three types of coatings were tested: 1) calorized, 2) aluminum dipped and 3) aluminum dipped and diffused. Base metals used were plain carbon steel and 4-6% chromium ½ molybdenum steel.

The Calorized coatings, produced by exposing the steel at high temperatures to a mixture of powdered aluminum, aluminum oxide and an energizer followed by a diffusion heat treatment, usually were thicker than the aluminum dipped coatings.

A microstructure of an as-received calorized coating is shown in Figure 11. This specimen had been tumbled during Calorizing which results in a smoother more deeply diffused alloy. Total thickness of the coating is .017-inch, with an overlayer of .005-inch. This should be compared with Figure 12 which is the same coating after an exposure of 9190 hours in the reformer reactor inlet at East Chicago 910-933 F, 500 psi, .0002 mol percent hydrogen sulfide. It is seen that a crack in the coating has developed but has not progressed into the base metal. The base metal has been decarburized and fissured due to hydrogen attack.

The aluminum dipped coatings were applied to both carbon steel and 4-6 Cr-½ Mo steel. During dipping in the molten aluminum some diffusion of aluminum into the base steel occurs and in addition a bright overlayer of aluminum adheres. During a subsequent heat treatment further aluminum diffusion occurs.

In the as-dipped state the aluminum coatings have the appearance shown in Figure 13. Slight penetration of the base metal is noted. However, most of the aluminum is in the overlayer.

Exposure of this coating for 1502 hours to 1.2 mol percent hydrogen sulfide at 672-683 F; 500 psi in the desulfurizer reactor effluent at Marcus Hook has caused diffusion of the aluminum along the ferrite bands of this "free machining" steel. See Figure 14. These "fingers" are quite hard as indicated by the diamond pyramid hardness indentations. Micro-hardness tests were

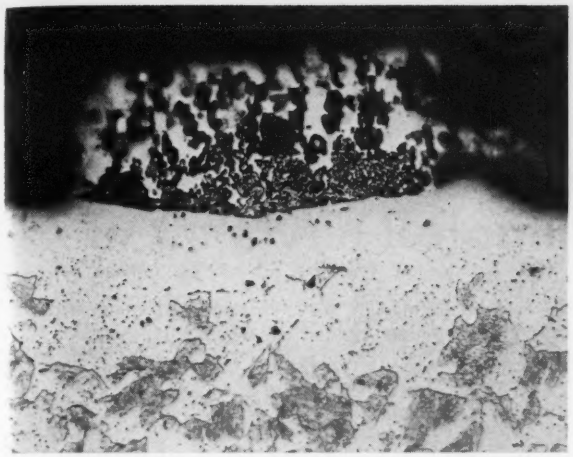


Figure 17—As-received aluminum dipped and diffused coating on 4-6% Cr-½ Mo steel. Outer layer is porous, discontinuous. Total thickness .004-inch. $FeCl_3$ etch. 500X

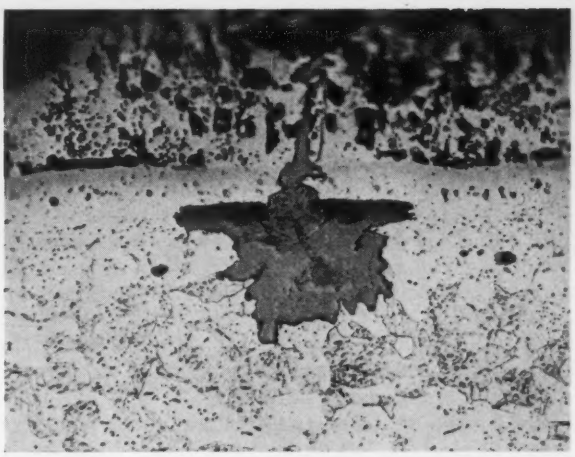


Figure 18—As-exposed aluminum dipped and diffused coating on 4-6% Cr-½ Mo steel. Note penetration and growth of iron sulfide beneath aluminum coating. $FeCl_3$ etch. 500X

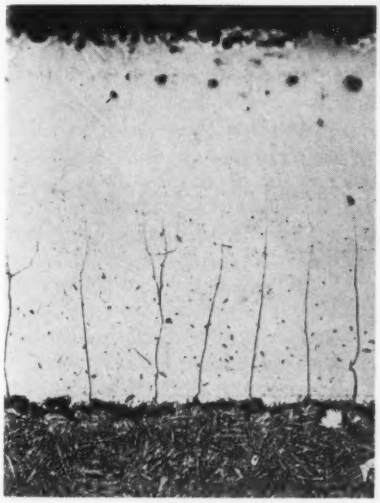


Figure 19—As-applied calorized coating on 4-6 Cr, ½ Mo steel. Thickness .010-inch $FeCl_3$ etch. 200X



Figure 20—As-exposed calorized coating on 4-6 Cr, ½ Mo steel. Slight roughening of outer layer, no base metal attack. $FeCl_3$ etch. 200X

made using a Bergsman Micro-Hardness tester attachment on the metallograph using a 50 gr. load. The as-exposed structures of the calorized and aluminum dipped and diffused coatings are shown in Figures 15 and 16 respectively. Hydrogen conditions at this location were insufficient to cause decarburization or cracking. For comparison the hardness of the diffusion zones of the other types of coatings is also given.

	DPH
Calorized coating	285-287
Aluminum dipped coating	673-762
Aluminum dipped & diffused	907-933

It is seen that the calorized coating is relatively softer than the dipped coatings. Differences in hardness are caused probably by the aluminum concentration gradient because the hardness of iron-aluminum alloys increases with aluminum content.

Although no other mechanical tests were performed on the aluminum coated steel the hardness readings suggest that the dipped coatings would be more brittle than the calorized steel.

Microstructure of the base steel (118-160 DPH) indicates the temperature of the aluminum coating process rather than the service temperature attained. Thus the normalized structure of the Calorized coated steel shows temperatures in excess of about 1600 F are attained in the Calorizing process. In the dipping process the temperatures are around 1300-1400 F as indicated by coalescence of the iron carbide in the base steel.

All of the coatings tested in the above location adequately protected the underlying steel from hydrogen sulfide attack. This, however, was not always true. In another test of aluminum coated 4-6% chromium steel, sulfide scale formed under a dipped and diffused coating, whereas the steel under the Calorized coating was not attacked. This is illustrated in Figures 17-20. The conditions of exposure at the Houston desulfurizer were 707 F, 250 psi, .086 mol percent hydrogen sulfide, 47 mol percent hydrogen, 1900 hours.

Apparently, cracks in the dipped coating allowed the hot hydrogen sulfide to come in contact with the base steel, forming grey "islands" of FeS which give off a faint odor of hydrogen sulfide when etched with dilute hydrochloric acid. Many of these islands were found, which on continued exposure probably would grow to the extent that the aluminum coating might be spalled off. This phenomenon has not been observed in aluminized carbon steels because of the better adherence and greater thickness of the diffusion zone in the plain carbon steels. Absence of

cracks in the thicker calorized coatings explains the absence of sub-coating sulfide attack of the 4-6% Cr steel.

Conclusions

As a result of studies of the hot hydrogen sulfide corrosion problem it is concluded that the hydrogen sulfide concentration is of prime importance. If it is lower than 100 ppm, design at temperatures of 750-950 F can be made on the basis of the hydrogen conditions and low chromium steels can be used. At higher concentrations, not until 13% chromium exists in the steel does the hot hydrogen sulfide resistance improve appreciably. Improvement in corrosion resistance correlates with 20-30 wt. percent chromium in the middle scale layer.

Evaluation of three types of aluminum coatings tested: Calorized, hot dip and hot-diffused was made by microscopic examination and micro-hardness tests. It is indicated that the thicker calorized coat is not as hard and is more protective of the base metal. Little of the aluminum overlayer in hot dipped coatings is lost in exposure and the aluminum diffusion zone increases in depth, but cracks in the coating can result in attack on base metal.

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Publication No. 57-3

High Temperature Sulfide Corrosion In Catalytic Reforming of Light Naphthas*

A Contribution to the Work of NACE Task Group T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry from Humble Oil and Refining Co., Baytown, Texas*

Abstract

When a catalytic reformer at Humble Oil & Refining Company's Baytown, Texas plant showed alarming pressure drop across the reactors after about 50 days' operation principally as a result of plugging with iron sulfide scale, immediate steps were taken to investigate the source of scale and the importance of metal losses occurring in the system. Over 600 pounds of iron dust was removed from the reactor and the unit put back in operation. In a month's time it was necessary to screen the catalyst again.

Heavy scale was found in the first exchanger on the reactor effluent stream both from the tubes and deposited from piping upstream. Catalyst was channeled and plugged.

When it became apparent the scaling was the result of sulfide attack and possibly severe corrosion in the furnace tubes and other components a testing program was begun. Several materials were tested at various locations in the stream by the electrical resistance method. Hydrogen sulfide content of the naphtha charge and recycle gas was determined.

Corrosion rates during operation on heavy naphtha varied from 0.15 to 0.4-inch on carbon steel and chrome alloys but the rate on 18-8 was about one-tenth that of the other metals. Chromium alloys through 12 percent in many instances showed corrosion rates higher than those of carbon steels.

In a laboratory pilot unit, tests indicated that aluminized steel generally showed good resistance and that hydrogen sulfide concentrations under 0.008 mol percent did not cause appreciable damage at temperatures about 1000 F. Humble plans to install a hydrofining unit to reduce sulfur content of the naphtha to about 40 ppm before it is charged to the naphtha reforming process. **3.2.2**

Introduction

EFFORTS to improve motor gasoline quality has resulted in an almost unprecedented rate of growth of catalytic reforming capacity in this country. This process has grown from practically zero in 1950 to an estimated capacity of nearly 1,300,000 barrels per day by the end of 1956.[1] One of the more serious operational problems accompanying the rapid expansion of this refining process has been high temperature sulfide corrosion and scaling of metals used in processing equipment. Corrosive attack by hydrogen sulfide has been experienced in varying degrees of severity in most catalytic reformers. In some units corrosion and scaling have been so severe that replacement of a large part of the system operating at high temperatures became necessary after very short periods of service.

Because of the rapid development of the catalytic reforming process to commercial scale, little information was available concerning the corrosion resistance of various alloys under these new operating conditions. For the most part the units were designed using experience gained from the older refining processes such as crude distillation, thermal and catalytic cracking and thermal reforming. Recent laboratory and plant corrosion studies by Backensto, Drew and Stapleford,[2] and a survey of pertinent data by Sorell and Hoyt[3] have shown clearly that corrosion experienced under catalytic reforming conditions is different in two unusual aspects from that experienced in the previously mentioned processes handling sulfur-bearing stocks. In catalytic reforming serious corrosion rates have been experienced at relatively low hydrogen sulfide concentrations. Also, contrary to past experience, the low chromium steels show little or no improvement in resistance to hydrogen sulfide corrosion over carbon steel under the catalytic reforming process conditions.

At present there appear to be only two means of preventing high temperature sulfide corrosion in catalytic reforming units. These are reductions of hydrogen sulfide content in the reaction system to a very low value and substitution of more resistant alloys such as the chromium-nickel stainless steels and possibly aluminum coatings.



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During the summer of 1955 the Humble Oil and Refining Company began operations on two catalytic reforming units at Baytown, Texas. One of these units, Catalytic Reformer No. 2, was built completely new and was placed in service on June 11, 1955. The other unit, Catalytic Reformer No. 1, was converted

★ Presented at a meeting of South Central Region, National Association of Corrosion Engineers, San Antonio, Texas, October 23-26, 1956.

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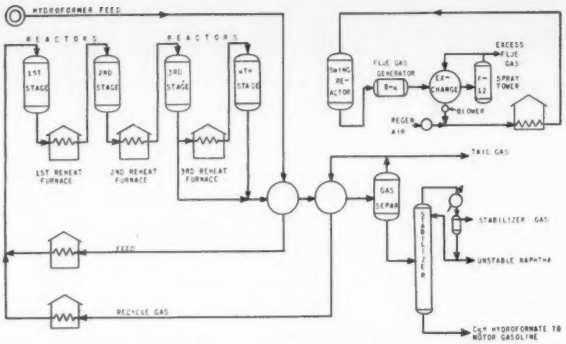


Figure 1—Simplified flow diagram of Baytown catalytic reforming units.

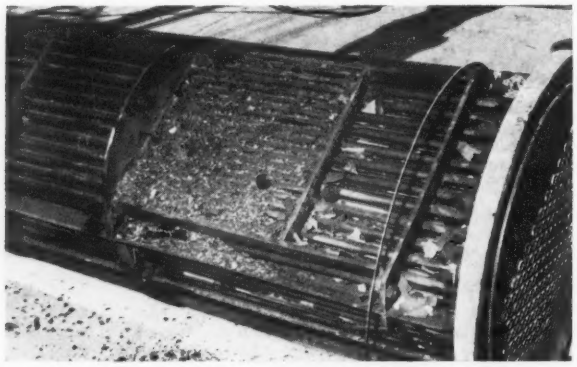


Figure 2—Showing accumulation of scale about 1¼ chromium ½ molybdenum tubes after four months' service in the first exchanger on the reactor effluent stream. Some of the scale was carried into the exchanger from piping upstream.

from an existing fixed-bed molybdena hydroformer and was placed on stream August 17, 1955.

Soon after the No. 2 unit was placed in service, difficulties were encountered with channeling and pressure drop increases across the reactors. This was principally a result of plugging with iron sulfide scale. The scale appeared to be forming in the furnace tubes and transfer piping as a result of high temperature sulfide corrosion. Because of the unusually high rate of attack indicated, a program was undertaken immediately to establish the severity of the corrosion problem. This paper presents first, a discussion of the high temperature sulfide corrosion problem encountered and second, the results of plant and pilot unit corrosion studies made to evaluate the effect of sulfur concentration on corrosion rates of several metals under catalytic reformer operating conditions. This study was made to establish whether tolerable corrosion rates on the existing metals in the units can be realized by process modification to permit operation at lower sulfur levels.

Description of Process

The principal objective of the catalytic naphtha reforming process is upgrading gasoline quality by increasing octane number. In addition, sulfur content of the naphtha is reduced and lead susceptibility is improved. In general, these improvements are accomplished by passing a mixture of hydrogen and feed naphtha over various solid catalysts at elevated temperatures and pressures. The catalyst promotes the desired chemical rearrangement of the hydrocarbon molecules. In the reaction zone virtually all organic sulfur compounds in the naphtha are converted into hydrogen sulfide. This has been the source of most of the corrosion difficulties encountered in catalytic reformers throughout the industry.

Figure 1 is a simplified flow diagram of the catalytic reforming units operated by Humble at Baytown. Three segregated virgin naphtha feeds which have been partly desulfurized are charged to the two units. The sulfur contents of the feed stocks vary from 0.008-0.01 weight percent on the light naphtha to 0.045 weight percent for the heavy feed, with an average of about 0.02 weight percent. The naphtha and recycle gas, principally hydrogen, are heated in separate furnaces and combined before charging to the reactors. The mixed stream then flows in series through several reactors with reheat furnaces between the reactors. These units employ a platinum on alumina catalyst. The reactor effluent after exchanging heat with the feed streams is freed of gas and charged to a stabilizer tower. Here light unstable naphtha is removed from the reformate product. A part of the gas recovered from the reactor effluent is recycled back through the reactors. Temperatures in the preheat, reactor and reheat systems range from about 800 to 975 F. Tube metal temperatures in the furnaces are somewhat higher. Pressures are approximately 300 psig.

High Temperature Sulfide Corrosion Problem

The first indication of corrosion was found when the lead reactor, at Catalytic Reformer No. 2, developed excessive pressure drop (30 psig) after about 50 days' operation. When the reactor was opened it was found that the inlet baffle had failed. This failure could not, however, account for all the pressure increase across the reactor. When the catalyst was removed from the reactor and screened, over 600 pounds of iron sulfide dust was removed from the catalyst. Although pressure drop across the lead reactor returned to normal after the first screening, after one month's operation the pressure drop had increased until screening of the catalyst again was necessary. During the first four months' operation it was necessary to dump and screen three reactors at this unit to restore normal reactor pressure drop.

Figure 2 illustrates the nature of the high temperature sulfide attack. This heavy iron sulfide scale was found after about four months' service on the 1¼ chromium-½ molybdenum tubes in the first exchanger on the reactor effluent stream. Some of the scale was formed in the exchanger and some was carried into the exchanger from piping upstream. Figure 3 is a picture of the catalyst bed in one of the reactors while it was being dumped for screening to remove the accumulated iron sulfide scale. A thin dense layer of the iron deposit can be seen on the very top of the bed. There is a layer of inert alumina hold-down balls on top of the catalyst bed. Plugging of the void spaces in the catalyst and the alumina

balls with iron sulfide has resulted in bridging of the catalyst. The catalyst below has fallen away from the plugged area in the top of the bed. Figure 4 is a lump of agglomerated catalyst lifted out of the reactor shown in Figure 3. This shows how tightly the upper portion of the catalyst is plugged with the iron sulfide scale. In these pictures the iron deposits are principally iron oxide because the reactor had been regenerated by burning with air and during regeneration most of the iron sulfide is converted to the oxide.

Since the presence of iron sulfide scale found in the reactors was evidence that severe corrosion probably was occurring in the system, immediate steps were taken to determine the magnitude of the corrosion without a shutdown of the unit for inspection.

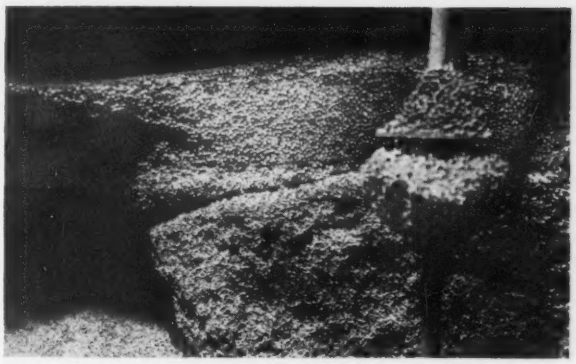


Figure 3—Effect of accumulated scale on catalyst bed.



Figure 4—Lump of agglomerated catalyst lifted from the reactor shown in Figure 3.

Plant Corrosion Testing Program

When it became apparent the pressure drop increase across the reactors was associated with possibly severe metal loss by sulfide corrosion in the furnace tubes, transfer piping and exchangers, a corrosion testing program was initiated to evaluate the severity of this problem. To measure corrosion rates under actual operating conditions, small by-pass flow assemblies were installed at the following locations on Catalytic Reformer No. 2: 1) Recycle gas furnace outlet; 2) Naphtha preheat furnace outlet; 3) Combined inlet to lead reactor; and 4) Last reheat furnace outlet. A flanged tee in these by-pass assemblies was used to support corrosion test specimens of carbon steel, 2¼ chromium, 12 chromium and 18-8 stainless (Type 347). These specimens could be installed and removed at will during the operation of the unit. Several corrosion rate measurements were made by exposing these metals to the

TABLE 1—Plant Corrosion Rate Measurements

S in Feed, Wt. %	H_2S in Recycle Gas, Mol %	Total S in React. Feed, Mol %	Test Location	Temp., F	Hour on Test	CORROSION RATE, IPY			
						C. Steel	2¼ Cr	12 Cr	18-8(347)
Charge Stock—Light Naphtha									
0.0087	0.0136	0.0154	Last Reheat Furn. Outlet	940	72	0.0745	0.0788	0.0907	0.0067
0.010	0.0125	0.0152	Naphtha Furn. Outlet	597*	23	0.0105	0.0041	0.0024	0.0027
0.010	0.0125	0.0152	Recycle Gas Furn. Outlet	947	23	0.0729	0.0849	0.1197	0.0094
0.010	0.0125	0.0152	Lead Reactor Comb. Inlet	895	23	0.0854	0.0825	0.1092	0.0077
Charge Stock—Intermediate Naphtha									
0.025	0.0387	0.0451	Naphtha Furn. Outlet	667*	96	0.0036	0.0084	0.0066	0.0043
0.025	0.0387	0.0451	Recycle Gas Furn. Outlet	928	96	0.1750	0.1804	0.1402	0.0056
0.025	0.0387	0.0451	Lead Reactor Comb. Inlet	850	96	0.1133	0.1273	0.1108	0.0106
0.025	0.0387	0.0451	Last Reheat Furn. Outlet	901	96	0.1444	0.1552	0.1368	0.0094
0.022	0.036	0.0413	Naphtha Furn. Outlet	580*	72	0.0045	0.0154	0.0054	0.0018
0.022	0.036	0.0413	Recycle Gas Furn. Outlet	956	72	0.1806	0.1971	0.1569	0.0188
0.022	0.036	0.0413	Last Reheat Furn. Outlet	912	72	0.1687	0.1885	0.1543	0.0128
0.021	0.0294	0.0365	Naphtha Furn. Outlet	644*	24	0.0034	0.0057	0.0004	0.0026
0.021	0.0294	0.0365	Recycle Gas Furn. Outlet	908	24	0.1050	0.1100	0.1019	0.0069
0.021	0.0294	0.0365	Last Reheat Furn. Outlet	900	24	0.1165	0.1080	0.1029	0.0051
Charge Stock—Heavy Naphtha									
0.0433	0.1357	0.1404	Last Reheat Furn. Outlet	930	96	0.398	.....	.....	.....
0.0453	0.1059	0.1149	Naphtha Furn. Outlet	683*	48	0.0089	0.0087	0.0058	0.0066
0.0453	0.1059	0.1149	Recycle Gas Furn. Outlet	937	48	0.3841	0.4004	0.3233	0.0421
0.0453	0.1059	0.1149	Lead Reactor Comb. Inlet	853	48	0.1899	0.2064	0.2014	0.0287
0.0453	0.1059	0.1149	Last Reheat Furn. Outlet	894	48	0.2899	0.2941	0.2370	0.0344
0.0327	0.0728	0.0796	Naphtha Furn. Outlet	703*	48	0.0157	0.0139	0.0086	0.0090
0.0327	0.0728	0.0796	Recycle Gas Furn. Outlet	829	48	0.1630	0.1878	0.1976	0.0224
0.0327	0.0728	0.0796	Lead Reactor Comb. Inlet	826	48	0.1478	0.1603	0.1580	0.0214
0.0327	0.0728	0.0796	Last Reheat Furn. Outlet	892	48	0.2343	0.2533	0.2231	0.0213

* Inlet to test assembly was on short dead-end line which caused low temperature.

process streams for various periods of time while the unit was operating on the various charge stocks. Test specimens were ribbons of shim stocks, 3/16-inch wide by 20 inches long and from 2 to 5 mils in thickness. Corrosion rates were determined by measuring the electrical resistance of the specimens before and after exposure, since the resistance of specimens with these dimensions is inversely proportional to their thickness. Final thickness of the specimen was calculated from the original thickness and the measured change in resistance. This method has been described by Dravnieks,[4,5] and Cataldi, Askevold and Harnsberger.[6]

Results of these corrosion rate measurements are shown in Table 1. During test periods, sulfur content of the naphtha charge was determined by a lamp combustion method followed by a nephelometric determination of the sulfur as barium sulfate. The hydrogen sulfide content of the recycle gas was measured by the Tutweiler method. The standard Tutweiler procedure was modified by using a 500 ml gas burette instead of the usual 100 ml size, and diluting the iodine solution to 0.0025 N. This procedure gave accurate check results with the cadmium chloride absorption method. The hydrogen sulfide concentration in the combined reactor feed was calculated for each test period from these data and the stream flow rates and composition.

Corrosion rates determined during operation on the heavy naphtha were extremely high, varying from 0.15 to 0.4-inch per year on carbon steel, 2¼ chromium and 12 chromium alloys. In this service the corrosion rate on 18-8 stainless was only about one-tenth that on the other metals. When charging the low sulfur light naphtha, corrosion rates were considerably lower, in the range of 0.07 to 0.12 IPY, but still at a level high enough to indicate a relatively short service life for much of the equipment. The intermediate naphtha operation gave corrosion rates intermediate between the light and heavy charge stocks. It is realized that these corrosion rate determinations are based on relatively short exposure periods and the corrosion rates shown are higher than would be experienced over long time service of the unit because of the increasing protectiveness of the ferrous sulfide scale as it increases in thickness.

One unexpected result observed in these plant corrosion rate measurements was the failure of chromium, up through 12 percent chromium alloys, to provide increased protection against the high temperature sulfide corrosion. In many instances the chromium alloys showed higher corrosion rates than carbon steel. This phenomenon, which has been reported by Dittrich[7] for mixtures of hydrogen and hydrogen sulfide, was later confirmed in pilot unit corrosion studies. Iron sulfide scale formed on the test specimens readily flaked off of the straight chromium alloys on cooling to atmospheric temperature. Films observed on the 18-8 specimens generally were thin and tightly adherent. The behavior of the scale formed on carbon steel specimens was erratic sometimes flaking off and sometimes remaining intact. None of the scales appeared to have significant mechanical strength.

Results of First Inspection at Catalytic Reformer No. 2

The alarming corrosion rates measured on the test specimens during the early operation of this unit indicated that the metal loss problem was serious enough to warrant a unit downtime for inspection.

First inspection of the unit was made in October, 1955 after a continuous run of 127 days. The purposes of this inspection were 1) to determine the extent and degree of corrosion throughout the unit, 2) to establish whether or not the unit could continue to operate safely for a reasonable period of time, and 3) to establish basic thickness measurements at several inspection points so corrosion rates could be more firmly established at the next inspection.

The following information was obtained as a result of the first inspection of the unit.

1. In general internal surfaces of all piping and exchangers which operate at temperatures of 600 F. or higher were found covered with iron sulfide scale which varied from 1/64-inch to almost 1/16-inch in thickness. Average thickness of this scale was about 1/32-inch. After the unit cooled down, large quantities of this scale came loose from piping and exchanger tubes and formed loose deposits in the equipment. Usually the flakes of scale ranged in size up to about 1 inch square. In some places, however, sheets of loose scale up to 1 square foot in area were found.
2. Furnace tubes in the preheat and reheat furnaces were internally scaled with a layer of iron sulfide about 1/32-inch thick.
3. Corrosion rates up to 0.2 IPY were indicated to be occurring in carbon steel and 2¼ chromium furnace tubes.
4. Average corrosion rates of 0.06 IPY were found in the 1¼ chromium reactor transfer and recycle gas lines, with maximum rates of 0.09 IPY.

Pilot Unit Corrosion Studies Under Platinum Hydroforming Conditions

Shortly after the high temperature sulfide corrosion problem was encountered at the catalytic reformer, a laboratory pilot unit program was initiated to study the effects of various process variables on the corrosion rates of several alloys. The principal purpose of this program was to determine the effect of sulfur concentration on corrosion rates and to establish whether tolerable corrosion rates on the existing metals in the unit could be realized by process modifications to permit operation at lower sulfur levels.

Description of Pilot Unit

The pilot unit used in these corrosion studies consisted of an electrically heated Type 304 stainless steel reactor 20 inches long having an inside diameter of about 7/8-inch; separate once-through hydrogen gas and liquid naphtha charging systems; and facilities for separating and measuring the gas and liquid product streams. A bed of fresh platinum catalyst (80 cc) was placed in the upper third of the reactor, while the lower two-thirds was used for exposing metal test specimens to the process stream.

Test Procedure

Weighed and measured specimens of several commercial alloys were suspended on a support in the vacant lower part of the reactor. Naphtha and hydro-

gen mixtures were heated in a preheat section of the reactor and passed down-flow over the catalyst bed and corrosion test specimens. Thus, the metals were exposed to a process condition simulating the lead reactor outlet or the first reheat furnace inlet on the plant reformers. Since once-through hydrogen was used, sulfur concentration in the pilot unit reactor was considerably lower than in the plant reformer at the same sulfur content on the naphtha feed. The reason for this is that a large part of the hydrogen sulfide produced from the decomposition of organic sulfur compounds in the plant units is returned to the reaction zone with the recycle gas. To produce sulfur concentrations in the pilot unit reactor comparable to the highest sulfur levels observed in the plant units, it was necessary to add approximately 0.15 weight percent sulfur as n-amyl or n-hexyl mercaptan to the heavy naphtha charge. Other sulfur levels were maintained by charging either the lighter naphthas alone or in various mixtures with one another.

Results of Pilot Unit Corrosion Studies

Table 2 lists the corrosion rates determined on the various alloys when operating the pilot unit for 96-hour test periods at several sulfur concentrations and temperatures. These corrosion rates were calculated from weight loss determinations after carefully removing the iron sulfide scale from the test specimens. The hydrogen sulfide concentration in the reactor was calculated from the difference between the total sulfur entering in the naphtha feed and the total sulfur found in the liquid product.

Black powdery corrosion products first began to appear on the test metals when the hydrogen sulfide concentration in the reactor reached the range of 0.006 to 0.007 mol percent. It was observed that carbon steel exposed to a hydrogen sulfide concentration of less than 0.006 mol percent at 1000 F was completely free of any surface discoloration or scale.

Results of pilot unit corrosion rate determinations at 1000 F. are shown in Figure 5. Here the corrosion rates for the various alloys studied are plotted against mol percent hydrogen sulfide in the reactor. Curve A in Figure 5 is drawn through the points for carbon steel. Curves B and C are for the 18-8 and 25-12 alloys, respectively. The chromium alloys up through 12 percent chromium grouped reasonably close to the carbon steel curve except in the hydrogen sulfide range of 0.008 to 0.02 mol percent. In this

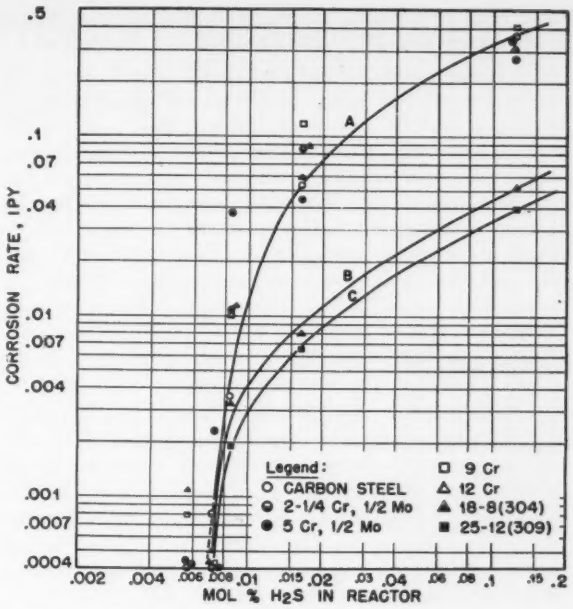


Figure 5—Corrosion rate versus hydrogen sulfide concentration under catalytic reforming conditions at 1000 F.

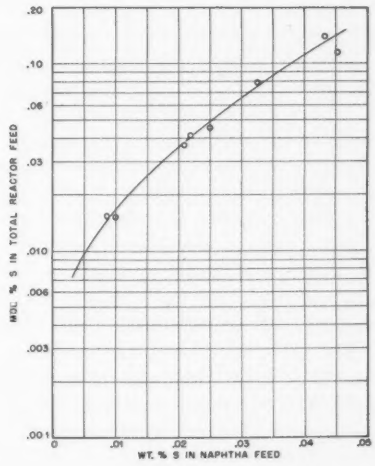


Figure 6—Sulfur concentration in reactors at hydroformer No. 2 vs sulfur concentration in naphtha feed.

TABLE 2—Pilot Unit Corrosion Studies Under Catalytic Reforming Conditions

Temp. F.	Total S in Reactor Feed, Mol %	Calc. H_2S In Reactor, Mol %	CORROSION RATES, IPY* AISI 1020 C. Steel	2 Cr—½ Mo.	5 Cr—½ Mo.	9 Cr.	Type 410 12 Cr.	Type 304 18-8	Type 309 25-12
1000	0.00096	0.00069	0.0007	0.0007	0.0006	0.0011	0.0004	0.0003	0.0006
1000	0.0054	0.0047	0.0005	.....	0.0006	0.0001	0.0007	0.0006	0.0005
1000	0.0062	0.0057	0.0004	0.0004	0.0004	0.0008	0.0011	0.0004	.....
1000	0.0078	0.0072	0.0008	0.0004	.....	0.0002	0.0005	0.0002	0.0004
1000	0.0094	0.0085	0.0036	0.0376	0.0108	0.0101	0.0113	0.0033	0.0019
1000	0.0176	0.0165	0.0540	0.0851	0.0404	0.1186	0.0866	0.0081	0.0066
1000	0.1261	0.1244	0.3671	0.2741	0.3667	0.4104	0.3063	0.0527	0.0395
1100	0.0046	0.0044	0.0009	0.0005	0.0016	0.0015	0.0030	0.0024	0.0013
900	0.0048	0.0044	0.0001	0.0001	0.0002	0.0004	0.0010	0.0006	0.0009
1100	0.0088	0.0077	0.0005	0.0004	0.0007	0.0010	0.0022	0.0022	0.0017
900	0.0096	0.0096	0.0002	0.0002	Nil	Nil	0.0070	0.0005	0.0002
1100	0.0270	0.0240	0.0640	0.1251	0.0918	0.0890	0.1167	0.0126	0.0127
900	0.0255	0.0247	0.1066	0.0781	0.1285	0.1293	0.1059	0.0056	0.0032

* 96-hour test period.

range the chromium alloys generally were attacked at a higher rate than carbon steel.

Test specimens of aluminized steel generally showed good resistance of the aluminum coating to hydrogen sulfide corrosion under these test conditions. However, at the higher hydrogen sulfide concentrations there was considerable attack on the uncoated edges of the sheared specimens and the aluminum coating was observed to be under-cut in many areas along these edges. The aluminum coating could be peeled back in these areas, exposing an iron sulfide scale on the base metal. This may have been the result of improper bond between the aluminum and steel, or damage to the coating as a result of cold work at the sheared edges.

It is significant that all metals tested began to corrode at essentially the same hydrogen sulfide concentration; i.e., 0.0075 to 0.008 mol percent. This is thought to represent a ratio of hydrogen sulfide-hydrogen at which the thermodynamic equilibrium of the system favors the formation of iron sulfide from iron and hydrogen sulfide at 1000 F as shown in Equation (1).

$$Fe + H_2S \rightarrow FeS + H_2 \qquad (1)$$

At hydrogen sulfide concentrations below this level, the hydrogen sulfide-hydrogen ratio is low enough to prevent the corrosion reaction from occurring and, in fact, the direction of the reaction is reversed so that any iron sulfide in the system will be reduced by the hydrogen.

A limited number of runs was made to determine the effect of temperature on corrosion rates in the critical hydrogen sulfide concentration range. Hydrogen sulfide concentrations could not be maintained exactly the same in the various runs and because the corrosion rate is extremely sensitive to sulfur concentration in the range studied, it is impossible to make direct comparisons between the runs. However, the data indicate qualitatively that corrosion rates on 9 chromium and lower alloys at 900 and 1100 F in the critical hydrogen sulfide concentration range would not be significantly higher than those at 1000 F.

From the data shown in Table 2 and Figure 5, it is concluded that corrosion and scaling of existing metals in the plant catalytic reformers can be eliminated essentially by reducing sulfur content in the naphtha feed to a level such that the maximum hydrogen sulfide concentration in the total reactor stream is 0.008 mol percent. In order to determine the desired maximum sulfur content of the naphtha feed, the data in Table 1 for feed sulfur contents and corresponding reactor sulfur concentrations were plotted in Figure 6. Extrapolation of this curve to 0.008 mol percent sulfur in the total reactor feed shows a maximum desired sulfur concentration in the naphtha feed of about 0.004 weight percent. It should be noted that the correlation shown in Figure 6 will be applicable only for the naphtha and recycle gas conditions associated with the catalytic reforming unit described herein. A somewhat different correlation may apply for other units because changes in molecular weight of the naphtha and recycle gas or changes in the ratio of recycle gas to naphtha will alter the mol percent hydrogen sulfide in the system.

Conclusions

Unusually high corrosion rates have been encountered in a catalytic naphtha reforming unit on metal surfaces exposed to the hydrocarbon and recycle gas streams at temperatures above 600 F. The immediate detrimental effect of this sulfide corrosion is the rapid increase in pressure drop across the reactors and channeling as a result of plugging with the iron sulfide corrosion product. A more serious deleterious effect is the anticipated high equipment replacement costs resulting from metal loss. Corrosion rates in the order of 0.2-inch per year in carbon steel, 2¼ chromium, 1 molybdenum and 1¼ chromium, ½ molybdenum furnace tubes and 0.09-inch per year in 1¼ chromium, ½ molybdenum transfer piping are indicated to be occurring at the current hydrogen sulfide concentration range of 0.015 to 0.12 mol percent in the reactor feed. Pilot unit corrosion studies indicate that high temperature sulfide corrosion and scaling on existing metals in the hydroformer can be eliminated essentially by reducing the sulfur content of the naphtha feed to a level such that the maximum hydrogen sulfide concentration in the total reactor stream is 0.008 mol percent. The desired maximum sulfur content of the naphtha feed is indicated to be about 40 parts per million.

Several means for reducing the concentration of hydrogen sulfide in the catalytic reforming units have been considered. These include Hydrofining of the naphtha feed to reduce the sulfur content, acid treating the naphtha charge for sulfur reduction and amine scrubbing of the recycle gas to remove hydrogen sulfide. Another approach to the solution of this corrosion problem is the substitution of the more resistant chromium-nickel stainless steels in critical high temperature parts of the system, or possibly the use of various aluminum coatings. Because local considerations may have such a great influence on the selection of one or the other of these corrosion control methods, there is no clear cut best solution for all refiners to the problem of high temperature sulfide corrosion in catalytic reformers. In order to eliminate the serious corrosion problems in the units described in this paper, Humble plans to install a Hydrofining unit to reduce the sulfur content of the naphtha to about 40 ppm before it is changed to the catalytic reforming process.

Acknowledgment

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Electrical Resistance Corrosion Measurements Employing Alternating Current*

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Abstract

An electrical resistance method, employing alternating current for measuring corrosion rates, has been developed. This method is based on the fact that when a low voltage, stable alternating current passes through the corrosion specimen, a small AC voltage drop is produced across the specimen. This small voltage drop is amplified and measured. Increases in voltages drop values so measured are directly proportional to the corrosion occurring.

It is shown that this method of corrosion measurement is applicable to systems containing distilled water at room temperature, closed recirculating tap water at temperatures above 170 F, flowing return line condensate, and possibly to tubular material in service. In all of the above applications, corrosion measurements may be made without interrupting the process or system. 2.3.5

Introduction

THE ESTIMATION of corrosion rates in many cases consists of exposing properly prepared, weighed metal specimens to the corrosive environment for a given time, followed by a suitable cleaning procedure and final weighing to measure metal loss. Such measurements are capable of a high degree of precision and are excellent when inhibition is essentially complete on identical specimens. However they also are laborious and are subject to errors arising from variations in the composition, structure, and preparation of the metal specimens, especially when corrosion inhibition is only partially complete.

Many aqueous corrosion processes occurring in the absence of inhibitors give metal losses that approach a direct proportionality with exposure time. In such instances, when the metal loss for a given area is plotted against time, the curve approaches a straight line. If an effective inhibitor is added to the system a curve of the metal loss against time will deviate from the curve obtained with the uninhibited or blank system, and the instantaneous corrosion rate (slope of curve) will approach zero at some exposure time. Comparison of the inhibited and uninhibited corrosion curves gives valuable information on the mechanism of inhibition and the degree of protection obtained. In any study of the effectiveness of a material as a corrosion inhibitor for a given process it is desirable that sufficient data be obtained to permit plotting a corrosion curve for both inhibited and uninhibited systems.

From a practical viewpoint corrosion inhibition need only consist of extending the useful life of a given piece of equipment to or beyond the time it would be worn out by normal use, at minimum inhibitor cost. For example, inhibition of cooling water for a condenser or a heat exchanger cooling a somewhat corrosive liquid need not provide immediate or complete protection on the cooling water side. Rather, the goal should be to provide protection to the cooling water side consistent with corrosion by the corrosive liquid. In such cases inhibitors can be employed which may require an appreciable time to bring the corrosion process under control.

When corrosion losses are determined by direct weighing of specimens it is obvious that much time and expense are involved, to say nothing of other complications such as space limitations or the undesirability of interrupting the process at intervals to remove specimens. Certain workers[1,2,3,4] have determined losses occurring during corrosion of the specimens by measurement of electrical resistance changes occurring in thin, narrow, and relatively long metallic corrosion specimens. These workers passed a known direct current through the corrosion specimen and measured the voltage drop. The electrical resistance of the corrosion specimen was then calculated from the values of voltage drop and current using Ohm's law. A series of corrosion measurements may be made on a single corrosion specimen without interrupting the process and, if desired, continuous measurements may be obtained. Such a series of measurements permits the plotting of a corrosion curve.

The above procedure employs a direct working current and is believed undesirable for the following reasons:

1. Bimetallic junctions such as soldered connections act as thermocouples and give rise to errors in instrument readings.
2. Electrolytes present in water conduct electrical current from one terminal of the test specimen to the other, and thus may give rise to galvanic corrosion.

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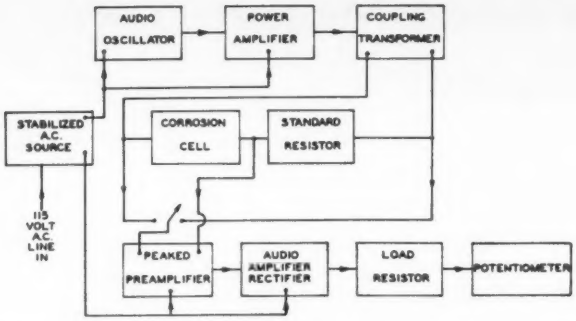


Figure 1—Block diagram of ac electrical resistance corrosion apparatus.

3. A direct working current is most conveniently obtained using storage batteries. Under some conditions the use of storage batteries is impractical, especially if it is desired to record data continuously.

In the work to be described, alternating current has been used to produce a voltage drop across the corrosion cell. This voltage drop is amplified, rectified, and measured. Such procedure either eliminates or greatly minimizes the above objections. Direct current arising from thermocouple junctions is eliminated because the amplifier blocks out direct current. Galvanic corrosion at anodic areas of the resistance corrosion cells is greatly minimized if not prevented by the use of alternating current. A constant voltage alternating working current may be readily obtained using suitable voltage stabilization.

Equipment and Procedure

Figure 1 is a block diagram of the alternating current electrical resistance corrosion apparatus and shows the relationship between the various components. A voltage drop is produced by passing an alternating current (working current) through the corrosion cell. The magnitude of the voltage drop varies directly with the electrical resistance of the corrosion cell. Simultaneously a comparative voltage drop is produced by passing the working current, in series with the corrosion cell, through a standard resistor whose electrical resistance approximates that of the corrosion cell. The voltage drops are separately amplified using a frequency peaked input amplifier, and the output of the amplifier is rectified and passed through a load resistor. Desired voltage drop selection is obtained by means of the selector switch shown, in Figure 1, feeding into the peaked preamplifier. The direct current voltage drop produced across the load resistor is measured with a potentiometer.

Even though all leads carrying voltage drops are shielded, a small amount of stray 60 cycle pick-up is almost unavoidable. Such pick up is obviously undesirable. A combination of a working current frequency considerably above 60 cycles and a frequency peaked amplifier largely attenuates stray 60 cycle pick-up. Audio frequency current of any desired frequency is generated by the combination of an audio oscillator and a power amplifier. This

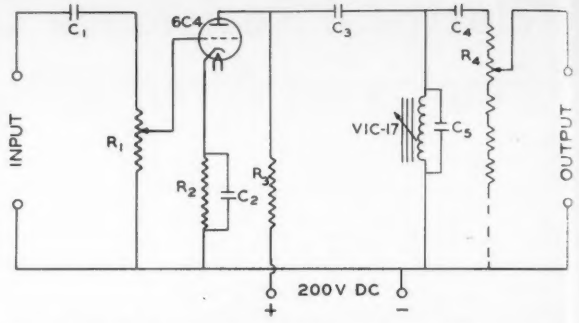


Figure 2—Peaked preamplifier. Code to letters is as follows: C1—0.1 microfarad, paper, 400 volt; C2—10.0 microfarad, electrolytic, 25 volt; C3—0.005 microfarad, paper, 600 volt; C4, 0.01 microfarad, paper, 600 volt; C5—Silver mica (0.704 microfarad, for 60 cps, 0.176 microfarad, for 120 cps, 0.0158 microfarad, for 400 cps); R1—1.0 megohm gain control, linear; R2—10.0 K; R3—200.0 K; R4—Voltage divider. 11—100 K resistors. All resistors 0.5 watts unless otherwise specified. VIC-17—10 henry variable inductor—UTC.

current is coupled to the working circuit by an appropriate coupling transformer. Control of the working current is effected either by a volume control in the oscillator or by variable resistance in the working circuit.

Preliminary voltage stabilization of the alternating current line voltage is obtained using a voltage-regulating transformer. This transformer gives an output voltage of 115 volts ± 0.5 percent, for input voltages over the range of 90 to 130 volts. It also supplies feed current for the audio oscillator, the power amplifier, the peaked preamplifier, and the audio amplifier-rectifier. While such stabilization is satisfactory for the above components, the requirements for the working current are more severe. Further stabilization of the working current is obtained by high voltage regulation of the power supply of the power amplifier.

Unit Components

The circuit of the peaked preamplifier[5] is shown in Figure 2. Maximum attenuation of stray pick-up is obtained when variable inductor VIC-17 and capacitor C5 are adjusted to resonance with the operating frequency. At an operating frequency of 400 cycles per second, attenuation of stray 60 cycle current amounts to between 98 and 99 percent.

Figure 3 shows the circuit for the amplifier-rectifier.[6] Inverse feedback into the input stage provides a high degree of linearity. The blocking condensers in the circuit prevent amplification of direct current voltages which may be developed thermally at bimetallic junctions.

Load resistor at the output of the rectifier has an optimum value of about 10,000 ohms. The potentiometer is a Leeds and Northrup student type or equivalent. Linearity of the combination is excellent up to an input voltage to the amplifier of six millivolts. Each millivolt reading on the potentiometer represents an equivalent input voltage to the amplifier amounting to 0.006 millivolt.

Figure 4 diagrams the circuit of the audio oscillator. This is a Wien Bridge oscillator for which output frequency is governed by the values of R1, R2,

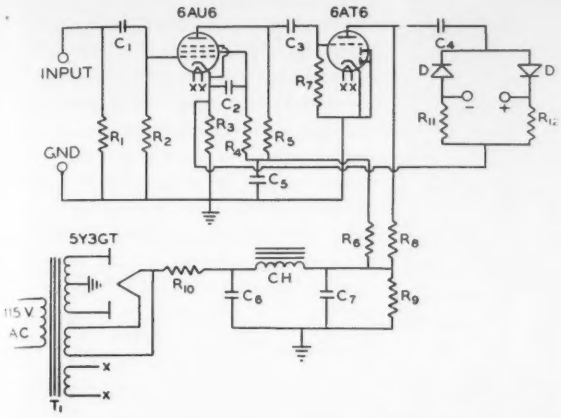


Figure 3—Audio amplifier-rectifier. Code to letters is as follows: C1—0.01 microfarad, paper, 600 volt; C3—0.05 microfarad, paper, 600 volt; C2, 4—1.0 microfarad, paper, 600 volt; C5, 6, 7—8.0 microfarad, electrolytic, 450 volt; R1—1.0 megohm; R2, 7—10.0 megohm; R3—10.0 ohms; R4—1.5 megohm; R5—0.47 megohm; R6—0.02 megohm; R8—0.10 megohm; R9—30.0 K, 10W, WW; R10—6.0 K, 10W, WW; R11, 12—4.7 K, matched. All resistors 0.5 W unless otherwise specified; D—IN35 dual germanium diodes; T1—Power transformer (240-0-240 volt, 40 ma; 5.0 volt at 2 amperes and 6.3 volt (CT) at 2.0 amperes); CH—8.5 henry—50 ma filter choke.

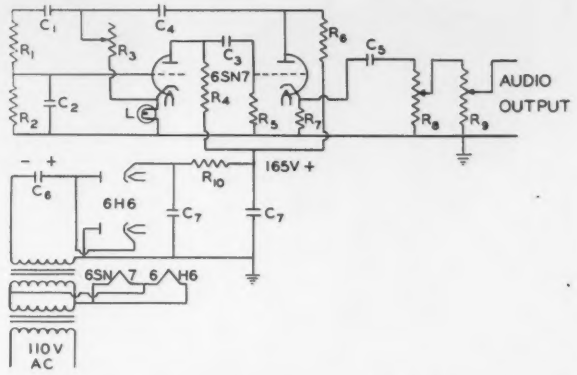


Figure 4—Audio oscillator. Code to letters is as follows: C1, 2—0.002 microfarad, silver mica; C3—0.02 microfarad, paper, 600 volt; C4—20.0 microfarad, electrolytic, 450 volt; C5—50.0 microfarad, electrolytic, 25 volt; C6—5.0 microfarad, electrolytic, 450 volt; C7—10.0 microfarad, electrolytic, 450 volt; R1, 2—0.2 megohm; R3, 8, 9—5.0 K wire wound potentiometer; R4—51.0 K, 1 watt; R5—1.0 megohm; R6—18.0 K, 1 watt; R7—1.0 K; R10—3.6 K, 5 watt. All resistors 0.5 watt unless otherwise specified; L—110 volt, 3 watt lamp; T1—Filament transformer, 6.3 volt (3 amperes); T2—Filament transformer, 6.3 volt (1.2 amperes). T1 and T2 are connected back to back.

C1 and C2.[7] The circuit constants as shown correspond to an output frequency of about 400 cycles per second.

The circuit diagram of the power amplifier is shown in Figure 5. This circuit is conventional except that the high voltage supply is electronically regulated.[8] Output for the working circuit is taken from transformer T4, which may be coupled to the working current load by convenient means, such as voltage-dropping resistors or a step-down transformer.

Satisfactory preliminary stabilization of the 115 volts input line current is obtained by the use of a Raytheon VR voltage stabilizer. The audio oscillator-power amplifier combination, previously described, provides a high degree of voltage stabilization for the working current.

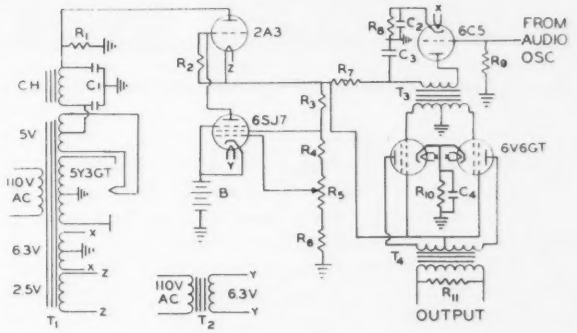


Figure 5—Power amplifier. Code to letters is as follows: C1—20.0 microfarad, electrolytic, 450 volt; C2—10.0 microfarad, electrolytic, 50 volt; C3—0.25 microfarad, paper, 600 volt; C4—50.0 microfarad, electrolytic, 50 volt; R1—20.0 K, 10 watt, wire wound; R2—0.47 megohm; R3—10.0 K; R4—22.0 K; R5—10.0 K linear; R6—4.7 K; R7—47.0 K, 1 watt; R8—5.6 K; R9—0.5 megohm; R10—250.0 ohm, 10 watt, wire wound; R11—500 ohm, 10 watt, wire wound. All resistors 0.5 watt unless otherwise specified; T1—Power transformer, 375-0-375 volt at 110 ma (5 volt at 3 amperes, 6.3 volt (CT) at 3.5 amperes, and 2.5 volt at 2.5 amperes); T2—Filament transformer 6.3 volt (CT) at 1.2 amperes; T3—Audio interstage transformer, single plate to push-pull grids, Thordarson Type 20 A 23; T4—Fixed impedance output transformer 10 KCT primary-secondary 500, 15, 8 and 4 ohm. Stancor A3311; CH—Filter choke 10½ henry, 110 ma; B—45 volt "B" battery.

Corrosion Cells

Corrosion cells may be constructed of thin metal strips, small diameter wires, or possibly even sections of metal tubing. Generally, the metal is quite long, say 8 to 18 inches, and has two flexible wire leads soldered or otherwise firmly attached to each end. One wire at each end will carry the working current, and the other wire will serve as a voltage drop tap. Obviously it is necessary to confine corrosion to that portion of metal away from the metal of the lead wires.

In the case of corrosion cells designed for total immersion it is necessary to seal the end with a suitable compound. Attempts to obtain information on sealing procedures from literature or otherwise[9] were negative. During this work several sealers were considered; room temperature-curing Epon 828 resin catalyzed with about 6 percent triethylenetetramine proved very satisfactory.

Figures 6 and 7 show construction of typical corrosion cells used in the present work. The corrosion cell shown in Figure 6 was made with rubber separators holding the test specimen, which was sealed into the upright glass tubes by means of Epon 828 resin. The corrosion cell shown in Figure 7 is preferred to that shown in Figure 6, because of a lesser tendency of the upright glass tubes to crack during operation. The transparent resin permits examination of the sealed portion of the corrosion unit at any time during or after a corrosion run. In no case was corrosion observed in the sealed part of the corrosion cell. In the test cells shown in Figures 6 and 7 the corrosion elements were made from both annealed steel wire and shim stock steel. Obviously many combinations are possible. Satisfactory operation of

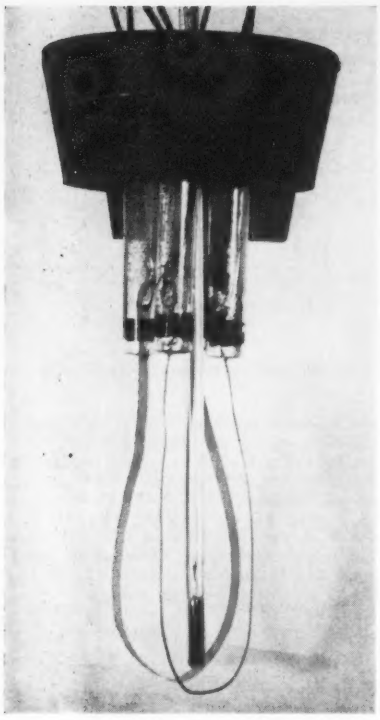


Figure 6—Typical corrosion cell rubber supports.

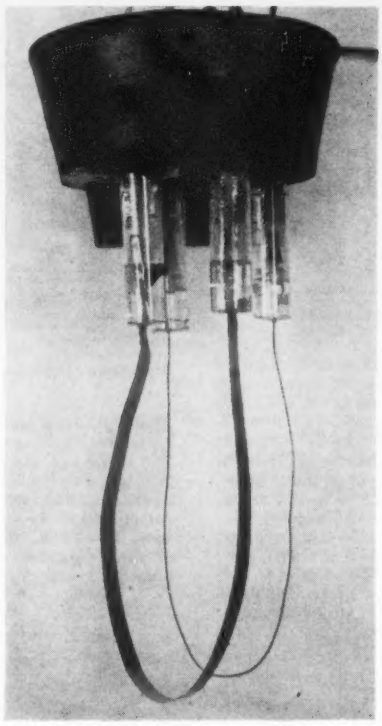


Figure 7—Typical corrosion cell polystyrene supports.

such cells has been obtained at temperatures up to 180 F. Higher temperatures have not been used. In some instances corrosion cells constructed with a rubber stopper mounting, as illustrated in Figures 6 and 7, may be used; in other instances it may be desirable to seal the corrosion cells in drilled pipe plugs, etc.

Temperature Compensation

All metals exhibit temperature coefficients of resistance. For metals such as iron, copper, and aluminum, the magnitude of the coefficient is such that corrections must be made in experimental data, if the temperature deviates appreciably from some average value. In this work an average temperature was taken as normal and data corrected using experimentally determined corrections. Temperatures were measured with a mercury thermometer. If corrosion losses are moderate it is convenient to apply a correction of a given number of millivolts per degree, subtracting for higher than normal temperatures, or adding for temperatures below normal. However, for high corrosion losses it is more accurate to apply temperature correction on the basis of decimal fraction millivolt drop change per degree temperature.

When corrosion cells are installed in remote locations, it becomes difficult or impossible to make manual corrections for temperature changes. Under such conditions cells duplicating the physical dimensions of the corrosion cell, but in which the metal wire or strip is totally sealed in glass tubes with epoxy resin, should be used simultaneously with the corrosion test cells for temperature compensation. This procedure has proven satisfactory for slow temperature changes but is unsuited for rapid temperature changes. Resistance cells containing exposed corrosion resistant metal, such as platinum wire, should be used if rapid temperature fluctuations are experienced.

Corrosion should occur only on that fraction of metal which is exposed, and changes in resistance measured should involve only that portion of metal. To calculate the amount of corrosion taking place it is necessary to know the exposed fraction of metal. This is done by measuring distance between the voltage tap junctions on the metal (wire or strip) before assembly and measuring the length of wire or strip embedded in resin after the corrosion cell is completed. For calculations, the initial voltage drop value is the total voltage drop of the wire or strip multiplied by the fraction exposed.

Standard Resistor

The standard resistor should approximately match the resistance of the corrosion cell and have a negligible temperature coefficient. If the corrosion cell has a resistance of about 0.1 ohm or higher, small precision wire-wound resistors are suitable. If the corrosion cell has a resistance appreciably less than 0.1 ohm, standard resistors may be constructed of 18 percent nickel silver (specific resistance about 2.9×10^{-5} ohm-cm at room temperature). The purpose of the standard resistor is to enable adjustment of the working current to some standard value during a corrosion test. The exact value is not important.

Operation

The corrosion measuring apparatus is assembled as shown in Figure 1. The corrosion cell or cells may be located at a considerable distance from the remainder of the apparatus. Consecutive measurements on standard resistors and on corrosion cells are easily accomplished with the selector switch. All voltage drop leads should be thoroughly shielded. It is imperative that the orientation of voltage drop leads be maintained unchanged during a corrosion test.

Before operating the apparatus it is necessary to peak the preamplifier to the operating frequency of the working current. This is done by turning on line voltage and allowing all circuits to warm up for one half hour. Output of audio oscillator should then be fed into input of preamplifier and VIC-17 (Figure 2) adjusted for maximum output, using a high impedance vacuum tube voltmeter or equivalent. This should be done at frequent intervals. For conven-

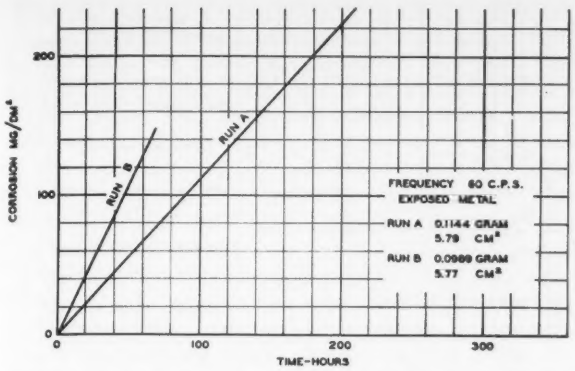


Figure 8—Corrosion rates of corrosion cells in distilled water. Run A is first run, shim stock steel corrosion cell; Run B is second run, corrosion cell used in Run A after cleaning.

ience, suitable connections may be made into the selector switch.

Although high degree of voltage stabilization is provided in the apparatus, small voltage fluctuations do occur. Compensation for such fluctuations is carried out by making all measurements as follows: (1) Balance potentiometer against the standard cell, (2) Read and record temperature of corroding liquid, (3) Set selector switch to standard resistor, the potentiometer to some convenient voltage (usually that of standard cell), and adjust working current to null galvanometer deflection, (4) Set selector switch to corrosion cell or temperature resistance cell and measure voltage drop on potentiometer; then record reading, (5) Repeat steps 1-4 until results are constant; record average voltage reading and temperature, (6) Convert average voltage reading at temperature of (2) to standard temperature and record as millivolt drop.

Calculation of Data

Since resistance changes are directly proportional to changes of voltage drop, corrosion occurring is calculated directly from changes of voltage drops. Increases of millivolt drop as obtained are proportional to the degree of corrosion occurring. Millivolt drop increase divided by the sum of the initial millivolt drop and the millivolt drop increase equals the amount (fraction) of corrosion occurring during the time interval concerned. The initial millivolt drop as used here equals the millivolt drop of the corrosion cell before corrosion has occurred, multiplied by the fraction of the metal specimen exposed. Weight of corrosion loss ocurring equals the weight of the exposed metal specimen multiplied by the fraction corroded. Corrosion per unit area is then calculated.

Corrosion in Distilled Water at Room Temperature Under Static Conditions

Corrosion occurring in distilled water at room temperature and under static conditions was measured by immersing a corrosion cell in distilled water in an exposed container. Figure 8 shows the data obtained. The curve marked Run A was made by immersing the corrosion cell for a total of 250 hours.

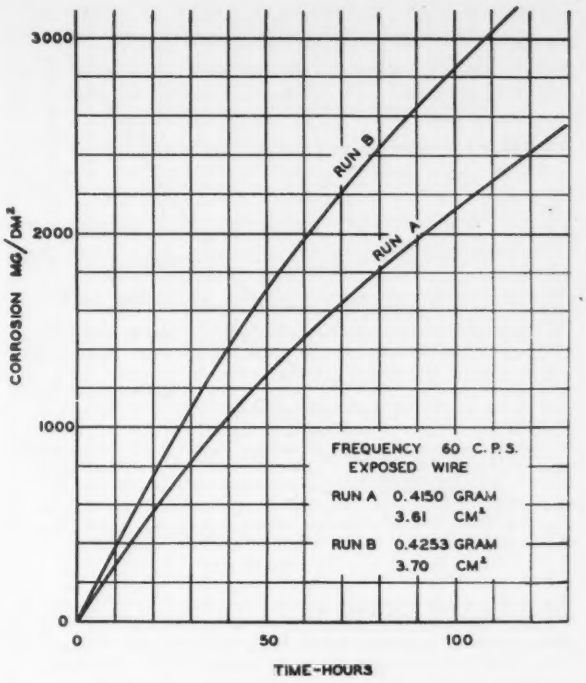


Figure 9—Blank corrosion rates of corrosion cells in closed circulating apparatus. No inhibitor was added. Run A is for cell in circulating tube-steel wire; Run B is for cell in reservoir-steel wire.

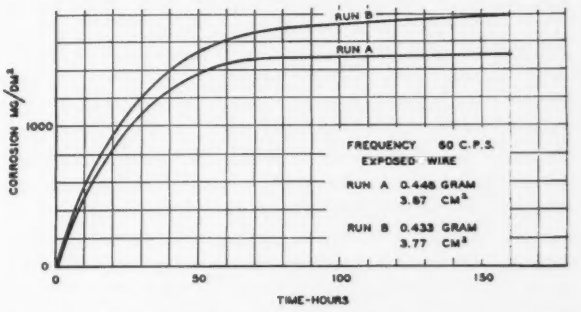


Figure 10—Corrosion rates of corrosion cells in closed circulation apparatus. Alkaline chromate was added after run was started. Run A is for cell in circulating tube-steel wire; Run B is for cell in reservoir-steel wire.

After cleaning the corrosion cell with hydrochloric acid and washing thoroughly to remove traces of acid, it was used in the second run (Run B). Corrosion rate of the second run will be noted to be somewhat higher than the corrosion rate in the first run. The corrosion products present in the distilled water were separated and analyzed for iron to obtain information on the accuracy of the resistance corrosion method. In Run A the calculated weight loss from resistance measurements was 15.1 milligrams and the weight loss by chemical analysis was 15.5 milligrams. In Run B, the calculated weight loss from resistance measurements was 6.8 milligrams and the weight loss by chemical analysis was 6.2 milligrams.

Corrosion in Closed Recirculating Systems at Elevated Temperatures

Corrosion study and evaluation of proposed in-

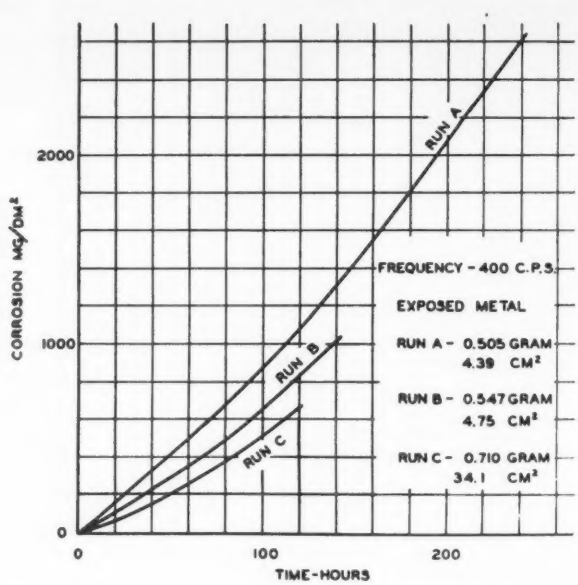


Figure 11—Blank corrosion rates for corrosion cells in flowing condensate. No treatment added. Run A is for cell made of steel wire and polystyrene supports; Run B is for cell made of steel wire and rubber supports; Run C is for cell made of shim stock steel.

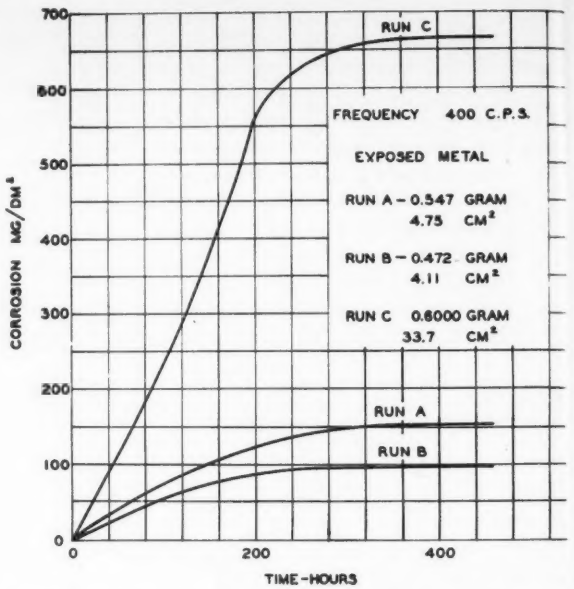


Figure 12—Corrosion rates for corrosion cells in flowing condensate containing filming amine. Run A is for wire cell in 2 ppm octadecylamine salt; Run B is for wire cell in 2 ppm octadecylamine alkaline emulsion; Run C is for shim stock cell in 2 ppm octadecylamine alkaline emulsion.

hibitors under closed recirculating conditions such as exist in the cooling systems of internal combustion engines was made on an apparatus described below. This apparatus was based on an original design by Max Herzog.[10] A 6-gallon metal container, equipped with an electrical heater, serves as a reservoir. Water flows downward from this reservoir to a circulating pump. From the pump the water is forced upward through a 5 foot section of 2-inch (inner diameter) pyrex glass pipe. The glass pipe normally contains weighed metal coupons. From the glass pipe the water passes upward through a glass lined circulating tube and finally discharges into the reservoir. One corrosion cell is placed in the circulating tube and a second corrosion cell is immersed in the reservoir. Normal operating temperature is 175 ± 5 F. Chicago tap water is used.

Two corrosion experiments were made with this apparatus. In the first experiment no inhibitor was used throughout. In the second experiment uninhibited tap water was used at the start and 2500 ppm of alkaline chromate added after 43 hours of testing. Corrosion cells for both experiments were made of steel wire.

Figure 9 shows corrosion rates obtained in the experiment without added inhibitor. The corrosion rate of the cell immersed in the circulating tube, Run A, is considerably lower than that of the corrosion cell immersed in the reservoir (Run B). This is unusual, especially when it is considered that the velocity of the water is much greater in the circulating tube than in the reservoir.

Figure 10 shows the corrosion rate obtained in the experiment in which alkaline chromate was added after 43 hours operation without inhibitor present. The initial portion of the curve (no inhibitor present) shows similar corrosion rates for the cells in the circulating tube and in the reservoir. The portion of the curve representing conditions after alkaline chromate was added shows almost complete passivation for the cell in the circulating tube (Run A), and only partial inhibition for the cell immersed in the reservoir (Run B).

After 165 hours the apparatus was drained, washed with hot tap water and refilled with hot tap water. Corrosion cells were not disturbed and no inhibitor was added. After reaching 175 ± 5 F the corrosion test was continued for an additional 96 hours. At the end of this time the corrosion cell of Run A was still passivated, while the corrosion cell of Run B was completely corroded through. These data are not shown in any graph.

After alkaline chromate was added in the run shown in Figure 10, the millivolt reading took a marked drop (from 798 mv to 748 mv for Run A, and from 793 mv to 705 mv for Run B). This decreased reading was a result of the increased electrolytic conductance of the solution. Portions of the curve after adding inhibitor were calculated using the millivolt readings obtained immediately after adding the inhibitor as new initial reading. Weight losses so obtained were added to the losses sustained at 43 hours. The same was done when tap water only was used for the preceding 96 hours.

Corrosion in Return Condensate Systems

Corrosion of return condensate systems was studied by methods designed to simulate typical operating conditions. High pressure steam (100 psig) was reduced by a regulating valve to 6 psig and then passed through a small stainless steel orifice, regulating flow to approximately 42 pounds per hour.

From the orifice, steam passed to a mixing chamber, where air and carbon dioxide were added at controlled rates. At this point provision was made for adding inhibitors. From the mixing chamber the steam passed into a vertical metal condenser concurrent with the flow of cooling water. The effluent from the condenser, at about 140 F, then flowed in series through two test coupon chambers. In this work, corrosion cells were inserted in one of the test coupon chambers.

Figure 11 shows corrosion rates obtained when corrosion cells were immersed in flowing condensate without inhibitor present. The corrosion rate curves, while not identical, are of the same order of magnitude and are approximately parallel. This is not unusual. Corrosion rate curves obtained by weight loss measurement show similar variations.

Figure 12 shows corrosion rate curves obtained when corrosion cells were immersed in flowing condensate containing 2 ppm of filming amine. The accuracy of the data obtained with the corrosion cells containing wire specimens (Runs A and B) and immersed in flowing condensate containing 2 ppm of filming amine is questionable because the exposed surface area is low. The exact slopes before final inhibition are not necessarily those shown in Figure 12. However, it is evident that both corrosion cells containing wire specimens corroded only moderately before final inhibition was effected. The corrosion cell containing shim stock specimens and immersed in flowing condensate containing 2 ppm of filming amine (Run C) corroded at a high rate during the initial portion of the test. After about 200 hours exposure, its corrosion rate started to decrease and after 320 hours reached almost zero. The type of corrosion rate curve obtained in Run C is very similar to that obtained from weight loss methods using flat cold rolled steel coupons.

The wire of the corrosion cell immersed in flowing condensate containing 2 ppm of alkaline emulsion of octadecylamine was cut off, cleaned with benzene and inhibited muriatic acid, and its weight compared to the calculated weight before immersion in condensate. Corrosion loss for 454 hours immersion amounted to only 1.6 mg—substantiating the slight corrosion indicated by the resistance method (3.7 mg). The difference in behavior of steel wire, and shim stock steel, immersed in flowing condensate containing 2 ppm of filming amines is very striking. Since these inhibitors function by laying down a non-wettable and impervious absorption film, it is possible that the adsorption mechanism is different for the two metals. Inasmuch as cold rolled steel is under greater internal stress than annealed steel wire, difference in adsorption between the two metals is not unexpected. Furthermore, shim stock steel because of the greater internal stress is usually subject to higher initial corrosion than is annealed steel wire. It should be informative to repeat these experiments using identical shim stock steel annealed in vacuum or in presence of inert gas.

Corrosion by Dilute Hydrochloric Acid Flowing Through Steel Tubing

An aspirator bottle served as a reservoir for a 1 to 20 dilution of hydrochloric acid. The diluted acid flowed by gravity to a Sigma pump from where it was pumped through a 36-inch vertical length of ¾-inch seamless steel heat-exchanger tubing and returned to the aspirator bottle. Total acid volume was 4000 ml. Aeration was obtained by blowing a stream of water-washed air through the acid. Voltage drop taps and working current taps were soldered onto the ¾-inch steel tubing; a length of 18 percent nickel silver served as the standard resistor. Coupling between the power amplifier and the working circuit was effected by means of a 110 volt—2½ volt center tapped, step-down transformer. Corrosion loss occurring was measured by chemical analysis of the acid solutions at the end of the corrosion experiment. Weight loss by chemical analysis amounted to 25 grams of iron while weight loss estimated from resistance measurements amounted to 15 grams of iron.

Conclusions

The alternating current resistance procedure described yields corrosion data generally in line with known facts, and may be used without interruption of many existing or continuing processes. It is believed to be a definite improvement over similar procedures using direct current; the circuits employed are capable of being made up in compact and portable form.

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DISCUSSIONS

Question by William L. Mathay, U. S. Steel Corporation, Monroeville, Pennsylvania:

Have you encountered any difficulties in applying electrical resistance techniques to pitted metal surfaces? Also, are the measurements influenced by corrosion products on the steel specimens?

Reply by W. L. Denman:

No difficulties have been encountered in applying electrical resistance techniques to pitted metal surfaces, although my experience with such surfaces has been limited. There is little reason to believe pitting would affect the data adversely, particularly if pitting is reasonably uniform. The author believes that pitting will affect weight loss measurements to a greater extent than resistance measurements.

Measurements are affected by corrosion products only when the corrosion products can carry current. Compact deposits such as sulfides do carry appreciable current and do affect the measurements. Hydroxides and carbonates do not.

Question by Norman D. Groves, Richland, Washington:

What are your findings and/or feelings with respect to heated specimens which would represent heat exchanger service? More pertinently, do you consider it feasible to use this technique to measure the corrosion occurring in stainless steel heat exchangers used to concentrate nitric acid?

Reply by W. L. Denman:

It is felt that the resistance technique can be applied to tubular service and particularly to measure the corrosion occurring in stainless steel heat exchangers used to concentrate nitric acid.

Any discussions of this article not published above will appear in the June, 1957 issue.

TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Analysis of Corrosion Pitting by Extreme-Value Statistics And Its Application to Oil Well Tubing Caliper Surveys*

By G. G. ELDREDGE

Introduction

ENGINEERING STRUCTURES such as pipe lines and oil wells may have a large number of pits and corroded areas of varying degrees of severity. The first perforation, whose time and location will be a matter of probability, may stop all use of the structure. For this reason the probability of such a failure must be known as well as possible.

It is not feasible to measure all the pits and it may not be possible to inspect the entire structure. The problem of the engineer is to make the best prediction of the probabilities of failure from the available data and then to decide how the probabilities may be minimized.

In this paper it will be shown how extreme-value theory helps the engineer in this task. As a particular application of the theory a new method has been devised for plotting and studying the data from an oil well tubing caliper survey. This has been called the Pit Depth Rank Chart. It provides a single value, the expected deepest pit, to express the results of a survey. Detailed instructions for its use will be given.

The extreme-value methods will be illustrated first of all by working with some published pitting data on underground corrosion. Besides the Pit Depth Rank Chart, which applies to data in a single oil well casing survey, a more general example of the use of the theory will be made in treating data from a series of wells to show the effect of upset portions of the joints on the pitting. Finally, a suggestion will be made for the further development of the theory.

A good introduction to the statistical theory of extreme values on which this work has been based is given in the lectures of Gumbel[1] and the corresponding tables.[2] This theory has been employed in such fields as flood predictions, weather, breaking strengths, life expectancies, etc. The rather frequent references to Gumbel[1] are sometimes given with a further reference to his numbered equations in the abbreviated form (G., 3.6) or a page reference (G., page 21) for the reader who wishes to make a detailed study.

Statistical Analysis of Pit Depths

The general problem of analysis of depth of pitting is to express the results (i.e., to characterize the many pits and their various depths by numbers that can be compared and so be useful in evaluating field corrosion experience). The major difficulties come from the fact that average pit depths cannot readily be used. In the first place the smaller pits become too indistinguishable to be measured, and in the second place the deeper ones are of the most practical importance. It is unfortunate that averages are not very useful inasmuch as they are so convenient statistically.

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Abstract

A detailed account is given of how extreme-value statistics can be applied to the analysis of depths of corrosion pits. Particular attention is given in this connection to pitting in oil well tubing as measured by caliper surveys. It is shown how pit depth data may be sampled and abstracted to give predictions of the expectation of deep pits and of perforation. The methods are illustrated by evaluation of the effect on pit depths of certain factors (i.e., upset ends and depth in well).

A special graphical method has been developed for analysis of tubing caliper surveys and related pit depth surveys; this is known as the Pit Depth Rank Chart. Detailed directions are given for its use. This chart takes into account the normal occurrence of the deepest attack toward the top of the tubing strings, but is also suitable if this does not occur.

2.1.1

Use of Extreme Values

In practice only the deep pits can be considered. What has usually been done in corrosion work has been to record the maximum pits on a specimen or in a given unit area, or to record the average pit depths of an assigned small number of the deepest pits. It even has been advocated to average all the pits deeper than an arbitrary depth and then to apply a correction for the pits neglected[3,4] but this, of course, would be quite laborious. The problem is to take into account and give proper weight to the information from the deepest pit, second deepest, third deepest, etc.

A solution to this problem is given by the statistical theory of extreme values. Extreme values are maximum or minimum values or second largest or smallest, or third largest or smallest, etc. All these and similar values are included in the term extreme nth values.

Just as averages of samples have a distribution or behavior which depends on the distribution of the values averaged, so extreme values of samples have a distribution which depends on the distribution of the population. Averages of samples from a normal distribution are themselves normally distributed. For individual values $X \pm \sigma_x$ from a normal population the sample averages are $\overline{X} \pm \sigma_{\bar{x}} = \overline{X} \pm \sigma_x/\sqrt{N}$. Even for populations not normally distributed sample averages are generally nearly normally distributed. Extreme values of samples will not be normally distributed even if the underlying population was normal. However, since work will be done with maximum pit depths, it is necessary to know how maxima will behave. In particular, it will be necessary to know the effects on the maximum (or other extreme nth values) of (1) the distribution of the population of depths of the individual pits (i.e., how they become rarer with depth), (2) the size of the area (related to sample size) from which they were selected, and (3) the biasing effect, if any, of averaging maxima. The following three sections give the explanations of these effects according to extreme-value statistics.

Distribution of Maximum Pit Depths

It has been recognized for a long time that maximum pit depths are not normally or symmetrically distributed. If the distribution of the population of all the individual pit depths were known, the distribution of maxima from samples could be obtained although it would be different from the original distribution. For example, if the probability of a pit as deep or deeper than x were known to be $1 - P(x)$ and the probability of a pit smaller than x were $P(x)$, then, by multiplying the independent probabilities, the probability that all of N pits would be smaller than that would be $(P(x))^N$. Scott[5] made this statement back in 1933 and referred to Tippett's[6] work on extreme values. At that time the theory was applied mainly to extreme values from a normal distribution. Scott's statement reads as follows: "We might expect therefore—and do actually obtain—a very asymmetrical type of distribution. The form of the curve which relates the average [of the maximum] pitting to the area will, obviously, depend upon the form of the distribution curve, as is indicated in the footnote on Tippett's equations. It is merely postulated here as an empirical fact that the form of the distribution of pit depths on a pipe line is such as to relate, with approximate linearity on the logarithmic coordinates, average maximum pitting with area over a considerable range in area. At least this is sufficiently accurate for all practical purposes."

Three Types of Extreme-Value Distributions. According to the theory of extreme values, distributions of maxima (maximum pit depths) can fall in three types, depending on how probable the deepest pits are.[1]

Type 1. Most pitting is expected to be of the exponential type (Type 1). This will include pitting where pits of any depth are possible but the probability of very deep ones, deeper than x, drops off exponentially as the depth x becomes greater. Where (G., page 21, first paragraph)[1] $F(x)$ is the probability that any pit is shallower than x, then:

$$1 - F(x) \to e^{-x} \text{ as } x \to \infty \qquad (1)$$

More precisely Type 1 includes distributions where all derivatives (the derivative of $F(x)$ is indicated by $f(x)$ and that of $f(x)$ is $f'(x)$ are continuous and tend to zero as the depth x becomes greater, along with the derivative of their successive ratios (G., 3.13 and 3.18).[1]

$$\frac{d^n}{dx^n}\,(1 - F(x)) \to 0 \text{ as } x \to \infty \qquad (2)$$

$$\frac{d}{dx}\left(\frac{1 - F(x)}{f(x)}\right) = \frac{d}{dx}\left(\frac{f(x)}{f'(x)}\right) \to 0 \text{ as } x \to \infty \qquad (3)$$

The Type 1 or exponential type of distribution of pitting includes the exponential distribution, normal distribution, log normal distribution* and many others (G., page 21, first paragraph.)[1] The probability (G., 3.16 and 3.17)[1] of maximum pits deeper than x approaches the right hand side of:

$$1 - \Phi(x) = 1 - e^{-e^{-a(x-u)}} \qquad (4)$$

where a and u are constants (G., 2.10, 3.6, and 3.7)[1] depending on the distribution of individual pit depths and on their number, n, per unit area. The expected maximum depth, u, is the depth with the probability $1/n$ of being exceeded, i.e., $1 - F(u) = 1/n$, and $a = nf(u) = f(u)/(1 - F(u))$. However, the distribution of individual pits will not ordinarily be known in practice, but only a sample of the distribution of maxima. Then, from the double-exponential equation (4), u and a can be obtained by plotting the observed maximum pit depths against the abscissas $-\ln(-\ln \Phi(x))$. Then u is the ordinate at zero abscissa and a is the slope. $\Phi(x)$ is the proportion of the maximum pits that are less deep than x.

Gumbel presents tables[2] and describes an extreme-value probability paper which can be used for plotting any data from Type 1 distributions without the use of the tables. Examples of the use of Gumbel's paper for pitting data are given below. This paper is not used for the Pit Depth Rank Chart to be described later; the latter uses semi-log paper.

Type 2. If pits of any depth are possible and the probability of very deep ones remains greater than e^{-x} and approaches A/x^k as the depth x becomes greater (A and k are constants greater than 1), the distribution is said (G., 3.12)[1] to be of Cauchy type or Type 2. For this type the logarithm of the maximum depth follows the equation just mentioned (G., following 3.19)[1] and plots linearily on the special paper described for Type 1.

Type 3. If there is a depth of pit that is approached but not exceeded, that is, the probabilities of all deeper pits become and remain zero, the distribution is said to be of the limited or truncated type. Gumbel

* In 1937 Martin[4] gave data to show that his underlying pit distributions did not have a normal distribution but had the logarithms of their pit depths normally distributed. He also gave some theoretical justification for this sort of distribution.

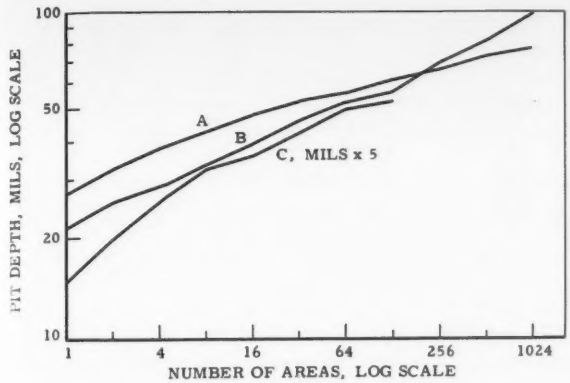


Figure 1—Log-log maximum pit depth versus area. Source of data and unit areas are as follows: A—Scott's data, Mt. Auburn (2,258 square feet); B—Scott's data, Council Hill (2,785 square feet); C—Ewing's data as taken from his curve (560.0 square feet).

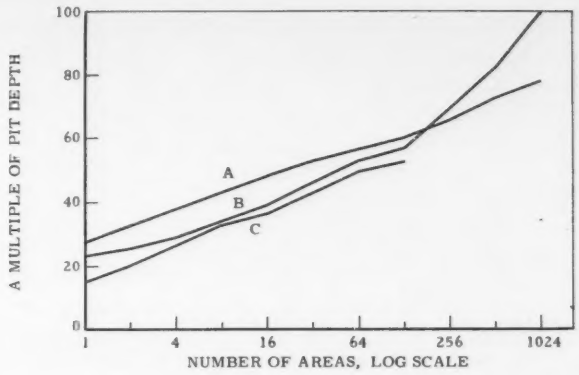


Figure 2—Semi-log maximum pit depth versus area. Source of data and unit area are as follows: A—Scott's data, Mt. Auburn (2,258 square feet); B—Scott's data, Council Hill (2,785 square feet); C—Ewing's data as taken from his curve (560.0 square feet).

gives equations for this type (G., 3.20 and following),[1] but it would appear that the observed maxima should be a good estimate of the expected maximum. This is the type of distribution which Evans[7] states is the only one for which the depth of the deepest pit constitutes a good criterion.

Effect of Area on Maximum Pit Depths

Most of the published discussions of pit depth statistics have tried to account for the effect of the area examined on the maximum pit depths. Two equations, those of Scott and Ewing,* have been suggested on an empirical basis. They would result from different distributions of pits.

Scott's Equation. It was found by Scott that maximum pit depth data were well represented by:

$$\overline{P} = bA^a \qquad (5)$$

where A is the area inspected and a and b are constants and $\overline{P}$ is an average of maximum pit depths from such areas (this is not the same "a" as used in the other equations in this paper). These would plot straight as $\overline{P}$ vs A on log-log paper. Scott's procedure for finding the average maximum pit depth for each area was as follows: The maxima for all the unit areas were averaged. Then the unit areas were paired in consecutive order and maxima from the double units were averaged. This procedure was repeated, N times altogether, ending with the maximum pit depth in all 2^N unit areas.

Scott's empirical equation corresponds to the theoretical Type 2 behavior of maxima according to which:

$$\frac{d \ln u}{d \ln N} = \frac{d \ln u}{d \ln \text{Area}} = \frac{1}{k} \quad \text{or} \quad \log u = B + C \log \text{Area} \qquad (6)$$

where u is the expected maximum pit for each size of area inspected and k is the constant exponent mentioned above for Type 2. This is from Gumbel's equation 3.8 with the value of a inserted where $a = f(u)/1 - F(u) \to k/u$ from the definition already given. B and C are constants. (Actually a correction for averaging would need to be applied to go from u to $\overline{P}$, but it would not be large. See the section on averaging below.)

Two of Scott's pit depth inspections are given in Table 1 and plotted in Figure 1. However, only one of these two lines is straight enough to indicate a good fit with his equation.

TABLE 1—Average Maximum Pit Depth Versus Area Inspected[1]

Multiples of Unit Areas	Scott's Data, Reference 5, p. 208		Ewing's Data, Reference 8, p. 60[2]
	Average Pit Depth, mils		Average Pit Depth, mils
	Mt. Auburn (Unit Area = 2,258 Sq. Ft.)	Council Hills (Unit Area = 2,785 Sq. Ft.)	Unit Area = 560 Square Feet[3]
1.....	27.59(1024)[4]	21.76(1024)[4]	74
2.....	32.91(512)	25.77(512)	100
4.....	38.04(256)	29.74(256)	136
8.....	43.33(128)	34.31(128)	166(53)[4]
16.....	48.11(64)	39.44(64)	182(28)
32.....	52.63(32)	46.19(32)	216(14)
64.....	56.50(16)	53.13(16)	250(7)
128.....	61.25(8)	57.25 8)	265(3)
256.....	66.25(4)	69.75(4)	
512.....	73.00(2)	82.50(2)	
1024.....	78.00(1)	100.00(1)	

[1] Plotted in figures 1 and 2.
[2] Depths estimated from the curve in Reference 8, page 60.
[3] One unit area is taken as ten lengths of the source data.
[4] Numbers in parentheses are numbers of maxima averaged, where they were given.

Ewing's Equation. The lower curve on this same Figure 1 is from data from Ewing who, as reported by the Bureau of Standards,[8] found maximum pit depths to be best represented by:

$$\text{or:} \quad \overline{P} = P_1(1 + C \log A) \qquad \overline{P} = P_1 + P_1 C \log A \qquad (7)$$

with P_1 and C being constants and A the area or number of unit areas. Data following this equation would plot straight as $\overline{P}$ vs A on semi-log paper. The lower curve of Figure 2 shows one of Ewing's pit depts inspections[8] replotted. The upper two curves are Scott's data again from Figure 1, one of which fits this plot better than his own.

Ewing's empirical relation corresponds to the ex-

* These names are used for identification and not necessarily to indicate discovery.

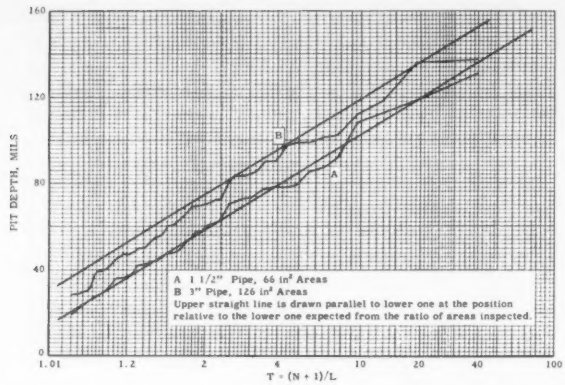


Figure 3—Bessemer steel pipe pit depths on extreme-value probability paper.

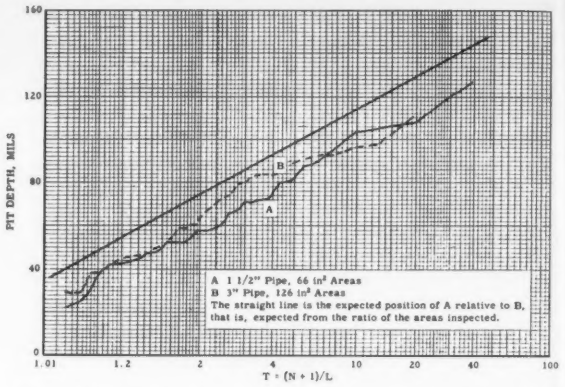


Figure 4—Wrought iron pipe pit depths on extreme-value probability paper.

TABLE 2—Effect of Area Inspected on Maximum Pit Depths[1]

Soil Rank No.	Depth of Maximum Pit, mils[2]			
	Bessemer Steel		Wrought Iron	
	66 Sq. In.	126 Sq. In.	66 Sq. In.	126 Sq. In.
1	131	137	127	(173)[3]
2	119	136	108	111
3	113	119	106	098
4	108	113	103	096
5	092	103	095	093
6	087	101	090	092
7	085	099	088	091
8	079	099	081	089
9	078	097	080	084
10	078	090	073	083
11	077	090	072	083
12	075	085	071	082
13	073	084	071	080
14	073	083	067	079
15	071	083	066	074
16	071	080	061	073
17	063	072	059	070
18	061	072	058	067
19	061	071	058	066
20	058	070	058	060
21	057	069	054	060
22	054	069	052	059
23	053	065	052	059
24	049	061	052	056
25	048	060	052	052
26	048	060	049	051
27	046	056	048	050
28	044	055	047	048
29	043	052	047	047
30	042	050	046	046
31	042	050	044	046
32	037	047	043	045
33	036	047	042	043
34	036	045	042	042
35	030	040	040	038
36	028	039	031	038
37	025	031	025	029
38	019	029	022	029

[1] Data taken from Reference 8, Page 59.
[2] These depths are plotted on the extreme-value probability paper, Figure 3, at abscissas equal to T = (38 + 1)/Rank No.
[3] This one value out of line and off the chart in Figure 3.

ponential class of the exponential type or Type 1 pitting where:

$$\frac{du}{d \ln A} = \frac{1}{a} \qquad \text{or } u = B + \frac{1}{a} \log A \tag{8}$$

This is from Gumbel's equation 3.8 with number of pits, n, proportional to area, A. For the exponential class of the exponential type, a is a constant.

For a normal distribution of individual pits, normal distribution class of Type 1, the following are approached for deep pits:

$$\frac{du}{d \ln A} = \frac{C}{u} \qquad \text{or } \frac{d \ln u}{d \ln A} = \frac{C}{u^2} \tag{9}$$

Both Scott's log-log and Ewing's semi-log curves should be concave downward with Ewing's semi-log curve the straightest. The C's here and below are constants to take care of the units of u, differing in some cases. For the normal class, a of Equation (8) approaches u.

For a log normal distribution of pits as advocated by Martin[4]

$$\frac{du}{d \ln A} = \frac{Cu}{\ln u} \qquad \text{or } \frac{d \ln u}{d \ln A} = \frac{C}{\ln u} \tag{10}$$

Here the semi-log curves of Ewing should be concave upward and Scott's log-log curve should be concave downward but more nearly straight.

The effect of area on the depth of the deepest pit can be analyzed in another way which applies to any Type 1 distribution. The distribution of maximum pits found can be plotted on the extreme-value probability paper described by Gumbel,[1] and extrapolated to areas even larger than the total area inspected. On such plots a change of the unit area inspected for maximum pits corresponds to a horizontal translation. The amount of this translation is equal to the logarithm of the ratio of areas (G., before 3.21).[1] Since the horizontal scale is close to simply logarithmic at its right hand end, the amount of this horizontal shift can be picked off at the right.

Figure 3 shows an extreme-value probability plot of data from the literature for pitting on two sizes of Bessemer steel pipe (Table 2 shows the data and method of plotting). The maximum pit depths observed have been arranged in order of successive depths and each maximum depth has been plotted at abscissa, T, defined as:

$$T = (N + 1)/L$$

on the probability paper, where N is the number of unit areas examined and L is the rank from the deepest pitted length, L = 1, to the shallowest (if the shallowest pitted length were pitted deeply enough to be observed) at L = N. It may be seen that the observed maximum pitting was deeper on the 3 inch pipe where the unit area inspected was 126 square inches than on the 1½ inch pipe where the unit area was 66 square inches. This difference in depth of pitting is just about that expected from the areas as

is shown by the dotted line drawn parallel and to the right with ratios of abscissas, at the right hand end, equal to 66 sq in/126 sq in. Gumbel (G., 2.8 and 2.17)[1] commonly counts the rank, m, from below instead of from the maximum so his N + 1 — m equals the L used here.

In Figure 4, however, similar data from inspection of the same areas and pipe sizes of wrought iron pipe show little effect of area. The dotted line shows the expected effect of area as in the previous figure. It appears likely, as suggested by Logan,[8] that there is here a counteracting specific effect of smaller diameter curvature giving more intense pitting. He quotes Shepard[9] for an electrochemical mechanism for this. From the near absence of area effect in Figure 4, this electrochemical effect of pipe diameter on maximum pit in the same area would appear to be nearly equal to the expected statistical increase in maximum pit depth for the increase in area, that is, about 14 mils. Besides the effect of the pipe diameter mentioned above, sometimes there may be other physical effects of area on pitting. For example, in a small area the presence of one pit, an anodic area, may inhibit other pitting electrochemically by polarizing the surrounding cathodic areas.[11]

Effect of Averaging Maximum Pit Depths

According to Gumbel (G., 3.39 with 3.8)[1]:

$$u = \overline{X}_N - \overline{Y}_N/a \qquad (11)$$

where u is the expected pit in each of N samples (each sample is assumed to contain a large number n of all pits). $\overline{X}_N$ is the average of N deepest pits and $\overline{Y}_N$ is an average of N tabulated values from the tables.[2] a is the curve slope defined above. Combining Equation (11) with Equation (8), it can be seen that:

$$u = B + \frac{1}{a} \log A = \overline{X}_N - \frac{1}{a}\overline{Y}_N$$

$$\overline{X}_N = B + \frac{1}{a}\left((\log N) + \overline{Y}_N\right)$$

so that $\overline{Y}_N$ becomes a correction to log N. This can be rewritten as:

$$\overline{X}_N = C + \frac{1}{a}(\log N) - (\gamma - \overline{Y}_N)$$

where B and C are constants and A is the number of unit areas (the same as N). The theoretical constant $\gamma = 0.5772157$ (G., 3.39)[1] is the value which $\overline{Y}_N$ approaches for very large values of N. The correction term $\gamma - \overline{Y}_N$ is 0.2107 for N = 1, 0.07883 for N = 2, 0.06437 for N = 15, and still less when more quantities are averaged.

The small effect of this correction is shown in Figure 2 by the square dots in the corrected positions. These square dots show the relative position of the top of the line if the corrections for averaging had been made.

Probability of Perforation

Curves on the extreme-value probability paper can be extrapolated to the right to show the number of specimens or unit areas expected to be necessary to give a pit deep enough to cause perforation. For all extrapolated portions of the curve abscissas can be interpreted as the expected additional number of areas that it would be necessary to examine, under conditions assumed to be the same, to find a pit of the indicated depth. That is, for the deepest pit of all in a series of areas or projected series, the rank is unity, and the +1 of N + 1 can be neglected and N becomes the quantity plotted against the depth. If the inspection procedure were only 50 percent efficient, the probability of perforation could be considered as applying to the uninspected 50 percent.

Utility of Extreme-Value Theory

It may be seen that extreme-value theory provides a distinct help for understanding the behavior of maximum pit depths. The situation does not remain as hopeless as it might appear (i.e., as was expressed by Evans[7] who concluded that only in cases where the distribution curve cuts the axis at a sharp angle instead of approaching it asymptotically (Type 3 distribution) does the depth of the deepest pit constitute a sound criterion. It is true that the unknown distribution of individual pits controls the distribution of maximum pit depths, but it is also true that for whole classes of distributions the resulting distributions approach a known asymptotic behavior and this behavior can be understood. The extreme-value probability paper allowing straight line plots and the equations that have been presented, and others in the literature, may be very useful in handling maximum pit depths. It has been shown how the statistical effect of the size of the area inspected for maximum pit depth can be taken into account and separated from any physical effect of the area.

Application of Extreme-Value Theory to Analysis of Tubing Caliper Data

As with other pitting, the problem of analysis of oil well tubing caliper data is to express the results in numbers (or curves) that can be compared. Tubing caliper measurements have been described by Chaney.[10] The caliper tool itself may have as many as 20 independently operating points of contact, any one of which measures the depth of any pit beneath it. Of course in some cases a pit may be missed, and corrosion product, scale, or deposited paraffin may make the pit appear more shallow than it is.

The steps in analyzing the data are as follows, starting from the original measurements:

1. The primary data are curves, traced on metal foil, whose peaks trace the depths of the pits in the casing. One inch of chart line on the metal chart represents about six lineal feet of tubing.
2. Photostatic copies of the metal chart are included with the report from the survey company. On these, one inch of chart represents about four feet of tubing.
3. The survey company interprets these charts by reporting the deepest pit in the

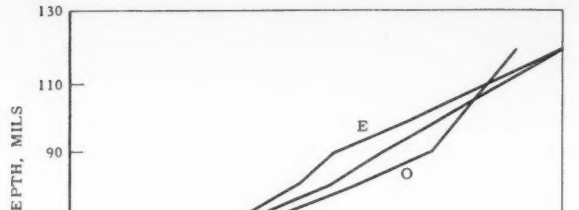


Figure 5—Maximum pits in odd and even joints in well, as plotted on extreme-value probability paper.

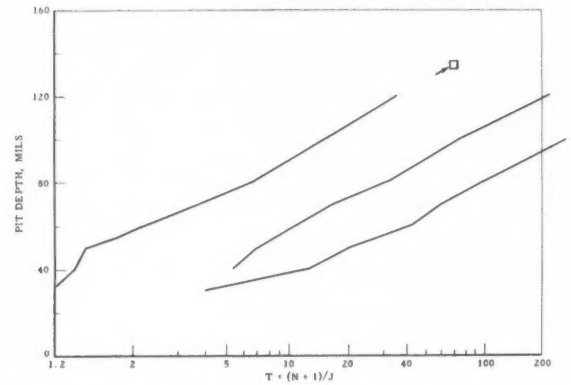


Figure 6—Maximum pits in higher and lower joints in well, as plotted on extreme-value probability paper.

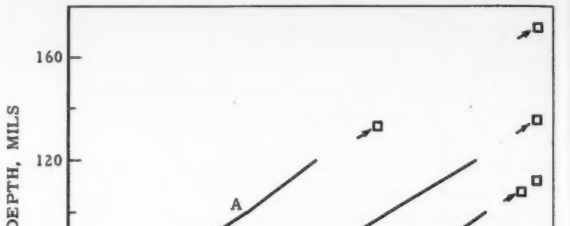


Figure 7—Tubing caliper surveys on semi-log paper. Curve A represents upper 67 joints, Curve B shows all 414 joints, and Curve C represents lower 347 joints.

TABLE 3—Oil Well Tubing Pitting, Odd Versus Even Joints

	No. of Pits			Rank			T = (Total Joints + 1)/(Avg. Rank)		
Depth, mils[1]	Even Joints	Odd Joints	All Joints	Even Joints	Odd Joints	All Joints	Even Joints	Odd Joints	All Joints
120	1	2	3	1	1–2	1–3	208	139	208
100	4	0	4	2–5		4–7	59.5		75.5
90	2	1	3	6–7	3	8–10	32.0	69.4	46.0
80	2	4	6	8–9	4–7	11–16	24.4	37.8	30.8
70	9	8	17	10–18	8–15	17–33	14.9	18.1	16.1
60	6	7	13	19–24	16–22	34–46	9.7	10.9	10.4
50	15	13	28	25–39	23–35	47–74	6.5	7.2	6.85
40	3	6	9	40–42	36–41	75–83	5.1	5.4	5.25
30	13	12	25	43–55	42–53	84–108	4.25	4.4	4.37
<30	152	154	306	56–207	54–207	109–414			

[1] These depths are plotted in Figure 5. For example, depth 120 mils is plotted at T = 139 for the odd joints curve.

TABLE 4—Oil Well Tubing Pitting, Higher Versus Lower Joints

	No. of Pits			Rank			T = (Total Joints + 1)/(Avg. Rank)		
Depth, mils[1]	Upper 67 Joints	Next 347 Joints	All Joints	Upper Joints	Next Joints	All Joints	Upper Joints	Next Joints	All Joints
120	3	0	3	1–3		1–3	34		208
100	2	2	4	4–5	1–2	4–7	15.1	232	75.5
90	3	0	3	6–8		8–10	9.7		46.0
90	4	2	6	9–12	3–4	11–16	6.5	99	30.8
70	14	3	17	13–26	5–7	17–33	3.5	58	16.1
60	11	2	13	27–37	8–9	34–46	2.12	40.8	10.4
50	12	16	28	38–49	10–25	47–74	1.40	19.8	6.85
40	4	5	9	50–53	26–30	75–83	1.32	12.4	5.25
30	8	17	25	54–61	31–47	84–108	1.18	3.9	4.37
<30	6	300	306	62–67	48–347	109–414			

[1] These depths are plotted in Figures 6. For example, depth 120 mils is plotted at T = 208 in curve B for the all-joints curve.

body and in the upper upset and lower upset portion of each joint. They do not report any pits less than about 30 mils deep.

4. The whole well survey could be represented by the maximum pit depth found in it. It turns out that this is a better method than might have been expected from its apparent dependence on only one pit and lack of correction for the fraction of the area surveyed. This last point about fraction of the area surveyed is discussed later. However a representative value for maximum pitting, depending on more of the survey than just its maximum, can be obtained from extreme-value theory.

The present statistical methods do not help in the difficult problem of reading the caliper charts. The statistics start with the reported numerical data. For example, Figure 5 and Table 3 show a comparison of odd and even joints in a caliper survey. The maximum pit depth for each joint was plotted on the extreme-value probability paper against the abscissa. The abscissa T is defined as $T = (N + 1)/J_{avg}$, where N is the number of joints surveyed and J is the rank of a joint. For the deepest pitted joint J = 1. For the next deepest pitted joint J = 2. J_{avg} is the average J for all the joints with the same reported depth. It is not important just where the plotting is discontinued at the low end of the curve. Here it is at 30 mil depth. Odd joints, even joints, or all joints give essentially the same curve.

Effect on Corrosion of Distance Down the Well

Another example, Figure 6 and Table 4, shows the effect of distance down the well on tubing pitting. In Figure 6 upper and lower joints were plotted separately in the same way as in Figure 5. The division between upper and lower was made so that about the same number of maximum pits deeper than 30 mils were in the two sections. If the sections had been equally pitted the two lines would have tended to coincide as in the preceding example. An extrapolation of the top curve can be made showing the deepest expected pit in the 67 joints measured. This extrapolation may be justified by considering that, since three pits were found in the 120 mil deepest group for the upper section, one of these three was probably deeper than the others. The other two curves extend too far to the right to be extrapolated on the extreme-value probability paper used.

The paper could be extended in order to extrapolate the others, but this is not necessary since it may be seen that its right hand portion is essentially semi-log paper,* and the latter paper can be substituted for the extreme-value probability paper if the plot is not expected to be straight too far to the shallow pit end. Figure 7 shows the data of Figures 5 and 6 plotted on semi-log paper. The abscissa, T, is defined as before. On Figure 7 the upper, lower, and total curves have been extrapolated to give the deepest pit expected in the section surveyed. It may be seen that the extrapolated maximum pit depths as well as the pit depth found were about the same for the upper 67 joints as for all the joints. However, the pitting intensity of the upper joints, if the same over as many as 414 joints, would be expected to produce a pit as deep as 184 mils. This is indicated by a further extrapolation to the abscissa 414 (Figure 7).

It has been demonstrated that the tubing corrosion surveyed decreases with depth in the well, and the same deepest corrosion is indicated by surveys that include a suitable number of joints from the top independent of just how many are taken. This behavior has been found in studies of tubing corrosion in several oil fields, including work with high pressure sweet oil wells and sweet gas-condensate wells.

Pitting in Upset Ends of Joints

In studies of tubing corrosion in several oil fields, it was found that corrosion tended to be more severe in the upset ends of the joints, at least at the upper ends. Figure 8 and Table 5 show maximum pit depths plotted on the extreme-value probability paper for 60 surveys in 13 wells in one oil field. These maxima were themselves each the expected maximum from a Pit Depth Rank Chart (explained below) of a survey. The pits from upper upsets, lower upsets, or bodies of the joints were considered separately. The lower upsets are definitely pitted deeper than the upper upsets, presumably from some effect of turbulence of the fluids flowing up past the joint, but possibly from some characteristics of the caliper mechanism.

To compare the upsets with the bodies of the

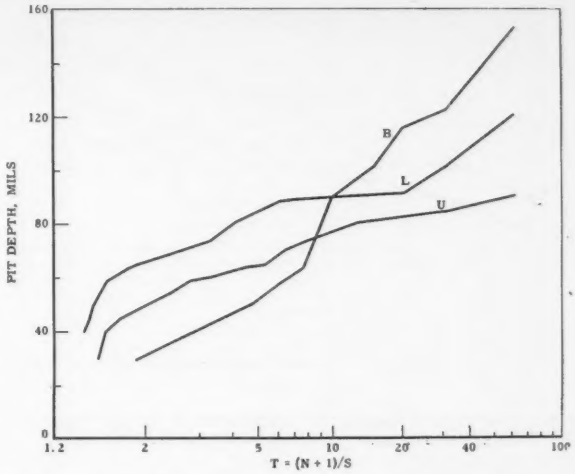


Figure 8—Maximum expected pit depths from 60 surveys. Upper and lower upsets and bodies of tubing joints are shown by curves.

TABLE 5—Effect of Upsets—Sixty Field Surveys[1]

Expected Depth of Pit, mils	No. of Surveys			Average Rank		
	Upper	Lower	Body	Upper	Lower	Body
152			1			1
121			1			2
120		1	0		1	
115		0	1			3
100		1	1		2	4
91		1	0		3	
90	1	4	0	1	5.5	
89	0	2	0		8.5	
88	0	1	0		10	
87	0	1	0		11	
86	0	1	0			
84	1	0	0	2	12	
80	4	5	0	4.5	15	
74	2	1	0	7.5	18	
70	2	9	0	9.5	23	6
68	0	1	0		28	
67	0	1	0		29	
66	0	2	0		30.5	
65	2	1	0	11.5	32	
64	1	0	0	13		
63	1	1	1	14	33	8
62	1	2	0	15	34.5	
60	6	3	1	18.5	37	9
59	1	1	0	22	39	
58	0	0	1			10
57	1	1	0	23	40	
55	1	0	0	24		
54	2	0	0	25.5		
53	0	1	0		41	
50	8	1	5	30.5	42	13
48	1	0	0	35		
47	0	0	1			16
45	1	1	0	36	43	
44	1	0	0	37		
42	1	0	0	38		
40	2	1	10	39.5	44	21.5
30	2	0	12	41.5		32.5
Not reported	18	16	22			
Total	60	60	60			

[1] Plotted in Figure 8. These 60 surveys were made in 13 sweet gas-condensate wells in one field in the period 1946-1954. Each expected deepest pit depth is from a Pit Depth Rank Chart for the survey.

* When extreme-value probability paper is not available, semi-log paper can be used by correcting the smaller values of the abscissa T by plotting at the logarithm of $T' = T/(1 + 1/2T + 1/3T^2 \ldots)$ instead of at log T. This can be shown by combining several of Gumbel's equations, solving G., 2.8 for F(x) and equating to $\Phi(x)$ of G., 3.16, $1 - 1/T = \Phi(x) = e^{-e^{-y}}$. This can be solved for the plotting position, y, and expanded giving the logarithm of the series above. It can be seen that no correction is needed at larger values of T, say, T greater than 4 where the plotting position approaches simply ln T (G., 3.45).

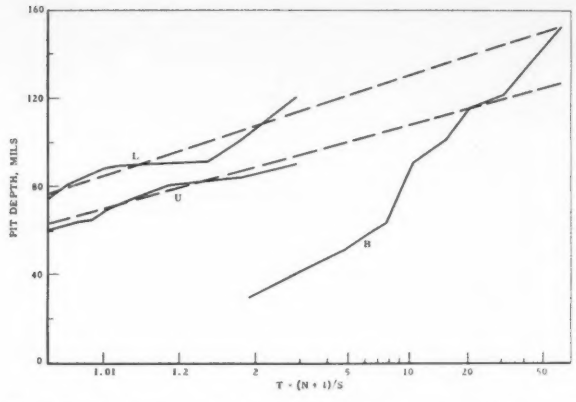


Figure 9—Maximum expected pit depths from 60 surveys. Upper and lower upsets and bodies of tubing joints are shown by curves.

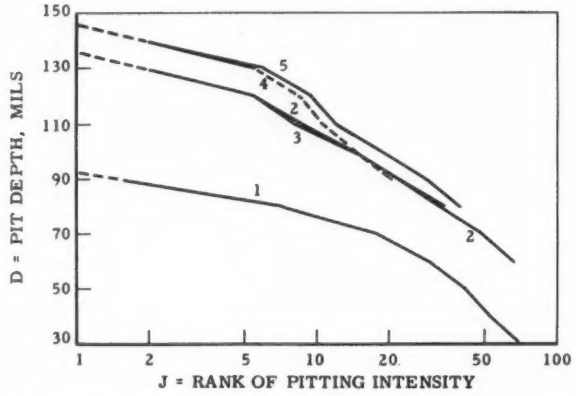


Figure 10—Pit depth rank chart. Data for curves are as follows:

Chart No.	Tubing Age Mo.	Joints Measured
1 1118-1119	39	145
2 108-109	49	271
3 1991-1992	55	176
4 4251-4252	66	180
5 4493-4493-2	79	130

joints it is necesary to allow for the difference in areas. It is not known just how much of the area of the joint was considered as being in the upset portion when the original charts were read. But on the assumption that the relative area is about 25 to 1, the dotted lines for the upset portions have been drawn in at a distance of ln 25 to the left in Figure 9, as explained above. The units in which abscissas are linear are $-\ln(-\ln(m/(N+1))$ so that, since the right hand end of the scale is nearly a log scale, the curve was shifted so the right hand end was at an abscissa 1/25th of its former value.

This shifted curve was then extrapolated back (dotted lines in Figure 9) to show the pit depths expected if the upsets had as much area as the bodies of the joints. Of course, if the relative areas were less than 25 to 1, this extrapolation would indicate less deep pits. With this ratio, however, it can be seen from Figure 9 that shallower pits are more prevalent on the upsets but very deep pits would be less prevalent than on the bodies.

Use of the Pit Depth Rank Chart

A good method of plotting tubing caliper data

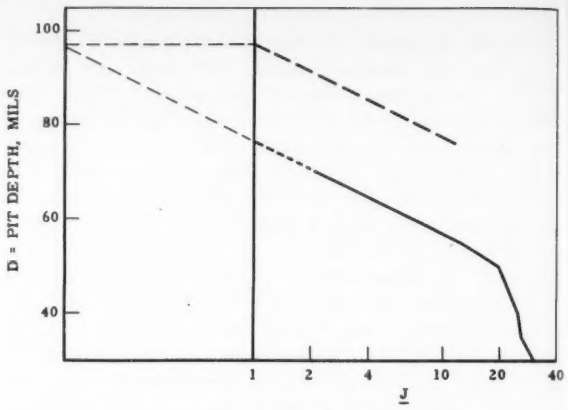


Figure 11—Control limit on pit depth rank chart.

from a single well should combine the following advantages:

1. It should make use of what is known of extreme-value theory, since the deepest (extreme) pits are of most importance.
2. It should be readily understood, be directly related to the original data, and be made easily.
3. It should not give different results from different numbers of joints surveyed in the well, even if the pitting tends to decrease toward the bottom of the well as was observed above.
4. Plots should be reasonably straight on paper that is readily available to everyone.

A suitable chart with these properties results from plotting the average rank of all joints having a given pit depth directly on the log scale of semi-log paper as shown in Figure 10. That is, J_{avg} is plotted instead of $(N+1)/J_{avg}$. The left hand ordinate is the expected deepest pit in the section measured. The data and method of calculation are shown in the special section on sample calculations.

Charts made in this way satisfy the requirements just given because:

1. They are equivalent to extreme-value probability paper except for the shallower pits which usually are observed to deviate from theory anyway. The shallow end of the curves can be dotted in past pits shallower than those with ranks one-fifth of the total number of joints surveyed. At $J/N = 1/5$, a correction of 10 percent could be added to J (correction = J/2N).*
2. The curve is readily understood since each point on it indicates the number of joints with pits deeper than a given depth.
3. The left hand axis indicates the deepest pit found or expected in the number of

* See previous footnote. Corrected $J = J' = J\left(1 + \frac{J}{2N} + \frac{J^2}{3N^2} \cdots\right)$

joints surveyed and for all data yet encountered the top sections of the well are most likely to include the deepest pitting. Therefore, the number of joints surveyed is not critical.

4. Semi-log paper is readily available, and the plots are usually smooth and fairly straight near the top.

As may be seen in Figures 10 and 11, the charts tend to be concave downward. The deviation is still present on extreme-value paper and indicates that the extreme-value theory for Type 1 distribution is not exactly followed. It may have to do with the fact that the distribution of pit depths in a given joint is not the same as the distribution in all joints as is assumed in the theory. (See last section of this paper for suggestions for further theoretical work.) For the present the charts had best be considered as a useful empirical method.

Usefulness of the chart has been demonstrated by the application to about 150 tubing capiler surveys.

Control Limits

The theory can also provide control limits for the Pit Depth Rank Charts. They can be drawn to exclude pits deeper than expected by chance once in ten times (or some other multiple) from the data on the rest of the survey.

On the Pit Depth Rank Chart a control line can be dotted in at ten times the value of the abscissa J, that is, parallel to, and to the right of the extrapolated best straight line. The dotted lines in Figure 11 show how this can be done. Thus, the control limit shows the expected depth of deepest pit in ten times the area surveyed, assumed to be of the same intensity of corrosion. Such depths could be expected with a 10 percent probability in a similar section surveyed. Gumbel (G., page 48)[1] discusses somewhat different, two-sided control limits. A pit depth falling above or near this line could be expected to be of a different nature or of having resulted from a different cause.

Suggested Further Development of the Theory

One way in which the distribution of pits in oil well tubing differs from those assumed in the theory is that the distribution varies with distance down the well. This hinders extrapolation to more joints as mentioned above and also casts some doubt on the use of the theory. The method as applied to a single well must then, at present, be considered as an empirical, though useful, one.

Extreme-value theory should be extended to cover methods for an analysis of the variance of maxima to distinguish causes of variance present in a single sample and affecting its maximum from causes of variance existing only between samples. Such methods would be analogous to the well-known analysis of variance methods in the statistics of normal distributions. Experience with the theory in each new application will, no doubt, also lead to other developments.

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TABLE 6—Data for Case 1

Joint No.	Top Upset	Bottom Upset	Body
1			90
2			90
3			130
4			70
5			100
..	....	....	....
..	....	....	....
108			50
111		70	
117			Numerous shallow pits[1]
124			40
126			Numerous shallow pits[1]
127			Numerous shallow pits[1]

[1] Numerous shallow pits not further tabulated.

TABLE 7—Summary of Case 1 Data, Plotted as Curve 5 of Figure 10

Depth, mils	No. Found	Rank[1]	Average Rank[1]
140	3	1–3	2
130	5	4–8	6
120	2	9–10	9.5
110	3	11–13	12
100	10	14–23	18.5
90	10	24–33	28.5
80	10	34–43[2]	38.5
70	16	44–59	51.5
60	5	60–64	62
50	12	65–72	68.5
40	7	73–79	76
30	14	80–93	86.5
<30	37	94–130	

[1] The rank is the cumulative number of deepest pits found. When more than one had the same depth, the average rank was put in the column to the right. These average ranks are plotted as abscissas in Figure 10.

[2] Pits plotted only on deepest pitted one-fourth or one-third of the 130 joints so none are plotted past the ranks of about 35 or 43; in this case plotting ended at rank 43, plotted at average rank 38.5.

TABLE 8—Data for Case 2

Joint No.	Percent Penetration			Deepest Pit, mils[3]
	Top Upset[1]	Body[2]	Bottom Upset[1]	
2			31	95
3			21	60
4			21	60
140			16	50
150		16		30
152		16		30
161			16	50
167		16		30
171			10	30
177			16	50
183		16		30
187		16		30
242			12	35
266		21		40
267		28		55
268		28		55
331			16	50
337	16			50
340			16	50
344			16	50
352	16			50
358			16	50
362			21	60
364	21		24	70
370			21	60
376	21		21	60
377			21	60
381			16	50
383			21	60
392			21	60
410	21		21	60
422			16	50

[1] Top upset and bottom upset. Total thickness = 300 mils.

[2] Body. Total thickness = 190 mils.

[3] Deepest pit. Computed from percent penetration and total thickness in order to combine pits on upsets with pits on body of joint. However, they can also be plotted separately. See text section on upsets.

to equations in this paper are given in the form, G., 3.18, and to pages as, G., page 21.)

2. Probability Tables for the Analysis of Extreme-Value Data. U. S. Department of Commerce, Applied Mathematics Series 22 (1953).
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APPENDIX—Sample Calculations for Pit Depth Rank Chart

For the benefit of the reader, sample calculations for Pit Depth Chart are included below. The calculations consist of plotting the pit depth P in mils against the logarithm of the rank J of the joint. The rank is the number of the joint, numbering from the ones with deepest pits to the ones with shallowest pits. The pit depths used are those given by the survey company as the deepest for the joint. Three cycle semi-log paper is suitable. The data ordinarily fall on a fairly straight line, except joints with the shallowest pits, that is, with ranks, J, greater than $J = N/4$ where N is the number of joints surveyed. The intercept of the curve with the rank = 1 line is the deepest pit expected in the total length surveyed.

Deepest pit in each joint whether in body or at upsets may be plotted; or upsets and bodies may be plotted separately. There are two cases: Case 1—Original Data Given as Pit Depth, Not Percentage Penetration (See Tables 6 and 7 and Figure 10), and Case 2—Original Data Given as Percent Penetration, Not Pit Depth (See Tables 8 and 9).

TABLE 9—Summary for Deepest Pit in Upsets and Body, Plotted as Figure 11

Pit Depth, mils	No. Found	Range of Rank	Average Rank, J
95	1	1	1
70	1	2	2
60	9	3–11	7
55	2	12–13	12.5
50	11	14–24	19
40	1	25	25
35	1	26	26
30	6	27–32	29.5
<30	386	33–428	..

Any discussion of this article not published above will appear in the June, 1957 issue.

Chemical Surface Preparation of Steel Prior to Painting*

By H. E. PATTERSON

Introduction

PAINT SYSTEMS have been steadily improved in an effort to produce more decorative, easier applied and more corrosion-resistant films. However, the ability of any paint system cannot be fully utilized without consideration being given to the metal surface to which it is applied.

In general, there are three types of surface contaminants on all metals which must be removed before painting to ensure maximum paint life. The completeness with which these contaminants are removed directly affects the ability of the paint to protect and decorate the metal. These three types of surface contaminants include:

1. Common soil such as grease, oil, and dust from rolling, forming, extruding, handling and so forth.
2. Rust and mill scale.
3. Visible and invisible rust stimulants.

In order for paint to adhere to the metal, it must be capable of wetting the metal surface. The presence of oil, grease, and other surface soil reduces the wetting action, and therefore, interferes with the adhesion of the paint film to the metal. Paint applied to an oily surface will develop less adhesion and in most cases will peel from the surface.

Oils and greases on the surface may be of two types: mineral oils or animal-vegetable oils. Mineral oils are insoluble in alkalies and acids and are unsaponifiable. The removal of mineral oils depends largely on straight dissolution by solvents or by emulsification. Animal and vegetable oils also are insoluble in acids and alkalies. However, they are saponified in treatment by alkali cleaners and their removal by alkali cleaning depends to some extent on saponification. They also are readily soluble in the common solvents and can be removed by emulsification.

Steel which is covered with mill scale also presents a problem in painting. Mill scale which in itself provides a degree of protection for the underlying steel is a constant source of trouble and leads to early failure of the paint system. This is due to the fact that mill scale will crack during shipping, fabrication and erection of the steel. As a result, corrosion of the underlying base metal will develop. Upon exposure or weathering of the painted steel part, large patches of the mill scale will loosen or lift, destroying the paint film and carrying it away. The rusting will continue and will undercut the remaining paint.

Rust may be classified as the same type of surface contaminant as scale. Partial removal of rust will not result in long paint life.

The third type of surface contaminant detrimental to long paint life is the class known as invisible rust stimulators. These are minute amounts of certain materials which accelerate the rusting of steel out of proportion to their concentration. Salts of sulfuric, hydrochloric and certain organic acids found in human perspiration are the materials most frequently encountered in this class. These invisible rust stimulators are effectively neutralized by phosphoric acid-solvent type metal cleaners and rust removers.

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Abstract

The proper surface preparation of metal prior to painting is becoming more and more important to industry. Experience has proven that a properly prepared surface will greatly increase the life of a paint system and the product and reduce maintenance costs.

Advantages and disadvantages of various types of cleaning are listed. Methods discussed include solvent cleaning, alkali cleaning, emulsifiable solvent cleaning, steam cleaning, and acid cleaning. Other topics covered include pickling, the treating of pickled metal, the use of inhibitors in pickling, and the use of phosphate coatings. **5.9.2**

Types of Cleaning

The term "chemical surface cleaning" covers a wide variety of cleaning materials and methods. Depending on the kind and degree of contamination to be dealt with, surface preparation can be accomplished by solvent wiping, vapor degreasing, alkali or steam cleaning, and emulsion cleaning if grease, oil and other surface soils are to be removed prior to rust or scale removal. Phosphoric acid cleaning should be used for removal of light rust, especially after wire brushing, sand blasting, etc. Mill scale should be removed by pickling the parts in sulfuric or muriatic acid.

Solvent Cleaning

Solvent wiping is the least effective of all the

chemical cleaning methods and yet it is still widely used today. With this type of cleaning a great variety of oil and grease solvents are employed to remove mechanically, dirt, dust and the oil film holding them on the metal surface. Materials such as mineral spirits, naphtha, coal tar solvents, alcohols, ethers, mixed alcohol ether compounds, petroleum fractions, chlorinated hydrocarbons, and many others are used for this type of cleaning. Normally, benzene, gasoline, and carbon tetrachloride are not used because of their toxicity and flammability. Solvent cleaning normally is used to remove heavy deposits of soil prior to a more effective cleaning method.

In all methods of solvent cleaning, except vapor degreasing, the solvent soon becomes contaminated with the removed dirt, oil, etc., and after a short time merely re-deposits it on the surface. In order to be effective, therefore, clean solvents must constantly be employed and this necessitates the use of large quantities of these materials.

Solvent cleaning can be applied by any one of the following methods: wiping, dipping, spraying, or vapor degreasing.

Wiping. Rags, sponges, brushes, etc. are dipped into the solvent and then applied to the metal surface which is rubbed or scrubbed with the rag, brush or sponge. Excess solvent and dissolved and diluted oil *must* drain from the surface for the removal of the contamination. If the solvent dries on the metal surface, the oil and grease will remain spread over the surface in a thin film. Therefore, it is necessary to use a second application of clean solvent to ensure the removal of the oil or grease. Otherwise, the residual film of oil and grease will interfere with the bond of the paint to the metal.

Dipping. Here the parts are immersed in a tank containing the solvent and depend upon the solvent to dissolve the oil or grease. The solvent soon becomes contaminated and the oil or grease is carried out on the part with the solvent. Usually two or more tanks containing the solvent are used and the one containing the dirty solvent is used for the preliminary cleaning.

Spraying. The solvent cleaner is sprayed under pressure on the part. Here impingement and dissolution of the oils are depended on to do the cleaning. The solvent then drains back into a tank, reservoir, etc., and is resprayed on the work. Once again the contaminated solvent problem is encountered which makes it necessary to use a second spray system to assure a clean surface.

Vapor Degreasing. The fourth type of solvent cleaning is vapor degreasing. Here the parts are suspended by means of hooks, racks, baskets, etc., into a tank containing the heated solvent. The solvent is heated and the vapors of the solvent condense on the cold metal and the pure liquid solvent dissolves and rinses off the grease, oil and other soils. The unique and most desirable feature of vapor degreasing is that the work leaves the machine through the vapor level and is there washed with the pure liquid solvent that has condensed on all of the surface. The parts thus not only are cleaned with uncontaminated solvent cleaner, but also are heated to the vapor temperature. On passing above the vapor level, they are quickly dried by evaporation before removal from the machine.

Vapor degreasing equipment normally has a solvent distillation unit where the contaminated solvent can be repurified and reused.

The advantages of solvent cleaning are as follows:

1. Solvents readily remove oil and greases.
2. They are easy to apply.
3. Equipment normally requires a minimum of floor space.

The disadvantages of solvent cleaning are as follows:

1. The solvent and applicator soon become contaminated with the oil and grease and, therefore, instead of removing the oil completely, only redistribute it.
2. If carried out properly the process is expensive.
3. With the exception of vapor degreasing, it normally constitutes a fire hazard.
4. It removes only oil and grease. It does not remove rust, rust stimulators, soaps, etc.
5. The fumes given off in many cases may be toxic.
6. Some of the chlorinated solvents are slightly decomposed by heat in contact with water and metal, thus forming hydrochloric acid. However, most of the vapor degreasing solvents are stabilized to neutralize any acid which is formed.

Solvent cleaning is normally quite an expensive operation. Solvents have a high initial cost and large quantities of solvents must be used to obtain a clean surface.

The cost of solvent cleaning will be between twenty cents to one dollar per 100 square feet of surface area. The cost will vary with the type of solvent used and the type of operation employed.

Alkali Cleaning

Alkali cleaning is more efficient and cheaper and is less hazardous than solvent cleaning. The principal methods of application of alkaline cleaners include the dip or soak tank cleaning, pressure spray cleaning and electrolytic cleaning.

Alkaline cleaners are dissolved in water and used at high temperatures. They clean by saponifying certain oils and greases and their surface active components wash away other types of contaminants. Soil removal is by detergency or saponification rather than by solvency. Soil is removed from the surface by displacement rather than by direct solution as in solvent cleaning.

The alkaline cleaning materials used today are generally blended alkaline compounds containing detergents, wetting agents, saponifying agents, and emulsifying agents. Some of the materials used in formulating this type of cleaner are trisodium phos-

phate, tetrasodium pyrophosphate, soda ash, caustic soda, sodium metasilicate and sodium orthosilicate.

Dip Tank Method. With this method the parts are immersed in the hot alkaline solution. Here agitation of the solution is important. Normally, this agitation is achieved by heating the solution to a rolling boil; however, occasionally it is necessary to add air agitation to the solution. This agitation tends to give a scrubbing action and flush away some of the soil. Dip tank cleaners normally are used at a concentration of 4-10 ounces per gallon and at a temperature of 180 F to boiling. The efficiency of this type of cleaning is increased with the higher temperatures.

Spray Process. Here the contaminated parts are sprayed with the alkaline cleaning solution, usually in a mechanical system. The hot solution is pumped from a heated reservoir and sprayed on the parts through a series of nozzles and then recollected in the same reservoir. The concentration of the cleaner used in the spray process is in general considerably lower than that used in the dip process. The concentration normally used is from 0.1-2 ounces per gallon and operated at a temperature of 160-200 F.

Electrolytic Cleaning. This method is similar to the soak type alkali cleaning. Here large quantities of gas are generated close to the surface contamination, an action which is very effective in providing the mechanical agitation or scrubbing needed in the cleaning process. High conductivity is important, which is why electrolytic cleaners usually contain excess caustic soda and are used at high temperatures and concentrations. Recommended concentrations are 6-14 ounces per gallon at a temperature of 180-210 F.

If the metal which has been alkali cleaned is to be subsequently painted, a very thorough water rinse is important. Residual alkali reacts with the paint film forming soaps which destroy the adhesion of the paint on the metal surface. Whenever possible, the treated parts should be given a final acidulated rinse. This acidulated rinse is a dilute solution containing chromic acid or a mixture of chromic and phosphoric acids. This thoroughly neutralizes any alkali on the surface and also leaves a thin film of chromic acid which is an excellent corrosion inhibitor. In this way an acidulated rinse will greatly prolong the paint life.

The advantages of alkali cleaning are readily apparent. Alkalies are highly effective cleaners and readily remove oils and greases. They are economical and non-toxic. The cost of alkali cleaning will range from ½¢ to 10¢ per 100 square feet of surface area depending upon the method of application, type of cleaner used, and the amount and type of surface contamination.

The biggest disadvantage in alkali cleaning is that it leaves an alkaline surface which is unsuitable for subsequent painting. However, this disadvantage is readily overcome by rinsing the surface with a dilute acidulated rinse.

Emulsifiable Solvent Cleaning

Emulsifiable solvent cleaning effectively removes heavy films of oil, greases, rust preventive compounds, waxes, etc. Here the solvent dissolves the oil and both oil and solvent are removed in the rinsing operation.

The emulsifiable solvents are diluted with four to ten parts of kerosene, mineral spirits or other petroleum solvents per part of emulsifiable solvent. The parts to be cleaned are normally immersed in the solution for one to five minutes. During this period, the solvent loosens and dissolves the surface soils which are flushed from the surface with a pressure spray rinse. The pressure spray rinse is employed because better and more effective rinsing is achieved and the force of the spray washes away the loosened soil.

Emulsifiable solvent cleaning sometimes is followed by application of an alkaline cleaner. The emulsifiable solvent removes heavy or encrusted films and the alkaline cleaner removes the light oil film left from the solvent cleaning solution.

The biggest advantage of this type of cleaning is the increased effectiveness in the removal of heavy deposits of oils and greases. The disadvantages are that first there is a low flash point which creates a fire hazard if certain solvents are used. There have recently been developed higher flash point solvents which minimize the fire hazard. A second disadvantage is the cost of this type of cleaning. The cost will range from ½¢ to $1.00 per 100 square feet of surface area, depending upon the solvents used and efficiency of method of application.

Steam Cleaning

Steam cleaning is used because the size, shape or location of the parts to be cleaned do not lend themselves to dip or spray cleaning.

Successful steam cleaning cannot be accomplished with steam and water alone. Various commercial detergents can be incorporated into the steam-water mixture which will be very effective in cleaning the surface for painting.

The cost of steam cleaning will be in the range of 20 cents to $1.00 per 100 square feet of surface area.

Acid Cleaning

Acid cleaning is another method of cleaning metal which has been thoroughly tested by years of experience. The principal ingredient is phosphoric acid to which has been added solvents, wetting agents and/or detergents to aid in removing the soil. This type of acid cleaning effectively removes grease, oil, dirt, etc., and also removes or neutralizes invisible rust stimulators. Unlike alkali cleaning, it removes light to heavy rust and minutely etches the surface of the metal and improves its paint adhesion properties.

The success of acid cleaning can be attributed to two important chemical reactions: (1) Removing the surface contaminants and, (2) Leaving on the surface traces of phosphoric acid which react with the metal surface, producing a thin film of insoluble iron phos-

phate. This thin film offers a good base for subsequently applied paint films and also retards the spread of filiform and other types of corrosion beneath the paint film.

Acid cleaners may be applied by the brush, dip and spray methods. The base cleaners may differ somewhat in the concentration of the phosphoric acid, and in the choice of solvents, wetting agents, etc., depending on the method of application.

The brush type method of acid cleaning includes two types of cleaners: the wash-off, and the wipe-off type.

The wash-off type is just what its name implies in that it is brushed on the metal surface and then rinsed off with water (preferably from a water hose).

The wipe-off type also is brushed or wiped on the metal surface using rags and wiped off with clean damp rags. The rags should be kept clean by rinsing them frequently in clean water and wringing them nearly dry.

The degree of rust determines the concentration of the acid cleaner used. For light rust, dilute one part of acid cleaner to five parts of water. For heavy rust, dilute one part of acid cleaner to one or two parts of water. Apply the diluted cleaner liberally to the surface of the metal with a brush and scrub thoroughly. If necessary, reapply the solution to the rusted areas until all rust is removed. Then rinse the surface thoroughly with water either from a hose or by wiping with clean damp rags. The paint film should be applied as soon as possible after the surface is thoroughly dry.

The dip method is the most widely used method of acid cleaning. The parts are first immersed in the hot or cold acid solution, then rinsed with water and finally rinsed in a warm to hot chromic acid solution, dried and then painted.

The acid cleaning bath may be used from room temperature to 180 F and at a concentration of 20-50 percent by volume. The concentration and temperature are usually adjusted so that the immersion time is 10 minutes or less. If the time required to remove the rust or scale in the stronger solution at the higher temperature exceeds 10-20 minutes, then it is suggested that muriatic or sulfuric acid be used. If sulfuric or muriatic acid is used, it should be followed by a water rinse. The parts then should be immersed in the phosphoric acid cleaning solution sequence described in the paragraph above to remove the residual sulfate or chloride corrosion stimulators and thus impart a more passive surface to the cleaned metal.

The advantages of acid cleaning are that they remove all three types of surface contaminants, namely:

1. Grease, oil, dust, etc.
2. Rust and scale.
3. Visible and invisible rust stimulants.

In addition, residues from acid cleaning are beneficial and improve the paint adhesion.

The disadvantages are that the dip and spray methods require acid proof equipment in the cleaning stage. The degree of results achieved are directly dependent upon the skill and care given to the operation.

The cost of acid cleaning will vary extensively depending upon the method used and the degree of surface contaminants present. The cost for the brush application will run from 40¢-80¢ per 100 square feet of surface area, principally because of the unavoidable loss of solution in use. For the dip process, the cost will run from 2¢-10¢ per 100 square feet of surface area. The cost for the spray process will run from 1¢-5¢ per 100 square feet of surface area.

Pickling

The next phase of good surface preparation is the complete removal of all oxides and scale prior to applying the paint film. This is accomplished by pickling off the oxides and scale from the metal. Pickling in the metal working industry is the process in which metals are immersed in acid solutions for the purpose of removing oxides or scale.

The various acids used in commercial pickling are sulfuric, muriatic, phosphoric, nitric, hydrofluoric or mixtures of the above. In general, sulfuric acid is the most widely used due to its availability, low cost, high boiling point and speed.

Pickling is usually carried out by immersing the parts in the pickle bath contained in suitable tanks. However, the same principles would apply if the pickle solution were sprayed or flowed over the work or if the work were pulled through baths of acid as in the continuous pickling of steel strip. Before such processes as rolling, drawing, annealing, etc., the metal is heated below the melting point, usually in an open furnace in which the oxygen from the furnace atmosphere combines readily with the hot metal to form oxides of iron and the alloying elements. On cooling, these oxides set as a hard, brittle and adherent scale coating. Scale is brittle, expands less than the iron and consequently cracks on cooling. Scale also is non-uniform in composition. The difference is due to the amount of oxygen present in each layer.

Scale is composed of four layers, with each layer having different amounts of iron and oxygen. The outer layer is, in general, richest in oxygen and may approximate the formula Fe_2O_3 containing about 30 percent oxygen by weight. Beneath the outer layer is a material generally constituting the bulk of the scale and corresponds to the formula Fe_3O_4 with about 28 percent oxygen. The next layer may approximate the formula FeO which contains about 22 percent oxygen. The last layer of scale is one that contains mixed oxides and metal of still lower oxygen content.

The outer layer is higher in oxygen and lower in iron. The oxygen content decreases and the iron content increases as the base metal is approached.

These outer layers which are high in oxygen are practically insoluble in normal pickling solutions. Therefore the cracks in the scale are used to permit the acid to penetrate to the inner layers of scale and to the base metal. These layers which are higher in iron and lower in oxygen are more soluble and react with the acid quicker than the outer layers. These inner layers being more soluble in acid are dissolved

more rapidly, allowing the bulk of the scale to fall off in the form of flakes. As the metal itself reacts with the acid, hydrogen gas is evolved which tends to "blow off" the outer layers of scale.

If all the scale were blasted off at the same time and the metal immediately removed from the pickling solution, there would be no need for inhibitors. This, however, does not occur since some scale is loose and is readily removed while other parts of the scale are very tight and take a much longer immersion to be removed from the base metal. The acid will continue to attack the base metal in the areas where the scale has been removed causing pits and wasting both acid and metal before the scale is removed from the other areas. This waste can be prevented and eliminated by using inhibitors which will be discussed later.

Acids also are used to remove other surface deposits such as lime scale, rust, and plated metals.

Rust is the most common of the surface contaminants for which acids are used to remove from the surface of the metal. Rust is a hydrated oxide of iron. It is more soluble in sulfuric, muriatic, and phosphoric acids than are the mill scales and, therefore, rust coatings are removed by being dissolved rather than by being blown off.

Rust, unlike scale, will continue to develop. Unless it is removed and the chemicals causing it to form are destroyed, rust will continue to form indefinitely even under coatings of paint, oils, waxes, etc.

The pickling process may be divided into the following steps:

1. Cleaning and preparation of the metal.
2. Pickling.
3. Treating the pickled metal.

Steps 1 and 3 will be discussed before considering pickling in greater detail.

Cleaning

The purpose of cleaning is to remove from the metal any surface contamination that will prevent the pickling acid from contacting the metal surface and removing the scale. Oil and grease are the most common surface contaminants generally encountered. Any of the previously mentioned methods of cleaning may be used. Normally, dip alkaline cleaning is used because it is relatively inexpensive and easy to accomplish.

The parts should be thoroughly rinsed with water after cleaning to remove the alkali, any residue of which if it were carried over would neutralize and waste some of the pickling acid.

Treating Pickled Metal

After pickling, the parts should be rinsed thoroughly in cold running water. This is necessary inasmuch as a thin film of the pickling acid and salts resulting from the chemical reaction of the acid with the metal clings to the parts. Both the acid and the salts, with the exception of some produced from phosphoric acid, actually stimulate rust and must be completely removed before they dry. Pickled work should be rinsed promptly, particularly if the acid is hot, since the dry acid salt film is difficult to rinse off and the residue will cause trouble in later operations.

When the pickling acid and salts have been removed or diluted, the metal must be treated suitably in preparation for the operations that are to follow. The operations of primary interest are to prevent the steel from rusting and to prepare the metal for painting. Weak alkali solutions using ¼ to ½ ounce per gallon of sodium carbonate, or trisodium phosphate are used in a boiling rinse after the cold water rinse to keep the parts from rusting. This alkaline surface produced will not rust rapidly, but if it is to be stored indefinitely or exposed to the weather, the surface should be oiled. This treatment is unsuitable for the application of paint.

Paint will not adhere well and will blister in a humid atmosphere if applied to an alkaline surface, since the residual alkali plus moisture acts as an electrolyte causing underfilm corrosion. The surface to be painted should be slightly acid and the best results are obtained when the pH of the surface is between 3 and 5. Phosphoric and/or chromic acid are the two acids used in the acidulated rinse to leave the surface on the acid side for painting. These two acids protect and passify the surface. Residues of muriatic or sulfuric acid stimulate rust and should not be used in the acidulated rinse.

It is noteworthy to mention here that there are some new paint systems developed recently which need a neutral or a slightly alkaline surface for best results.

Acids Used

As previously mentioned such acids as muriatic, sulfuric, nitric, phosphoric, hydrofluoric, etc., may be used in the pickling operation. However, muriatic and sulfuric acid are the main ones used because of cost, handling, availability and pickling speed.

Concentrated sulfuric acid will neither attack steel nor remove scale. It must be diluted with water before it can be used as a pickling solution. Sulfuric acid does not appreciably attack mild steel until it is diluted with an equal volume of water. The rate of attack of a sulfuric acid solution at a constant temperature increases tremendously as the concentration of the acid increases up to a concentration of approximately 39 percent by volume. The rate of attack will then decrease with the addition of more acid until at a concentration of approximately 50 percent by volume the action of the acid will stop and it will not attack steel. Therefore, sulfuric acid may be used at a concentration of from 1-39 percent by volume. Pickling baths are normally operated in the range of 2-20 percent by volume using the lowest concentration of sulfuric acid that will do the job in a reasonable amount of time.

Muriatic acid differs from sulfuric acid in that the rate of attack increases with the concentration until the maximum attack is reached by using undiluted commercial grade 20 degree Bé muriatic acid.

While the activity of the acid solution within the usual pickling range is proportional to its strength,

the activity of a pickle bath also is markedly affected by its temperature.

The rate of attack of sulfuric acid at 140 F is approximately 400 times greater than at 100 F. At 180 F it is approximately 1300 times greater and at 225 F it is 4000 times greater than at 100 F.

During the process of pickling with sulfuric acid, the acid reacts with the scale and base metal, dissolving a small amount of scale and a much larger amount of metal forming a contaminant known as iron sulfate. The presence of iron sulfate has a significant effect on the pickling. As the iron sulfate increases, the bath becomes sluggish, causing an increase in the immersion time necessary to remove the scale. As the iron sulfate increases, there will be an appreciable reduction in the activity of the acid. Due to this build up of iron sulfate, a point is reached where it is uneconomical to add more acid to the solution.

At approximately 2½ pounds per gallon of $FeSO_4 \cdot 7H_2O$, the adding of acid to the solution is discontinued and the temperature raised to maintain the same immersion time. By gradually raising the temperature, the same pickling time is maintained and more of the good acid used up in the pickling tub. In this manner, it is possible to reduce the amount of the good acid being drained in the spent solution. This helps to reduce the cost of pickling and also aids in the disposal problem by having less acid of which to dispose.

Agitation is another factor that greatly influences the pickling process. Baths of any fixed concentration and temperature will pickle faster if agitated. This is because the acid at the surface of the metal picks up more and more iron sulfate and quickly loses strength, causing a slowing down in the scale removal. With agitation fresh acid is brought to the surface and the sulfate-contaminated acid is dispersed throughout the solution resulting in faster scale removal. Agitation also washes off particles of loosened scale. Agitation is normally produced by the steam used to heat the pickle bath. The steam may either be discharged through holes in a lead pipe near the bottom of the tank, or it may be discharged through an injector type nozzle.

Considering the effects of the concentration, temperature, iron sulfate, and agitation, a reasonable method for operating the bath becomes apparent. Since a fresh bath contains no iron sulfate, it can be operated at a relatively low temperature and with an acid concentration ranging from 2-20 percent by volume as may be necessary to complete the pickling in the time alloted. As the iron sulfate increases and slows the pickling, the action can be speeded either by increasing the strength of the acid or the temperature of the bath. Both of these methods are used, but since to increase temperature in most installations means to use more steam, the agitation of the bath also is increased.

The best method is to keep the acid strength constant and to increase the temperature to offset the slowing action of the accumulating iron sulfate. It will be found that when pickle baths have dissolved approximately 2½ pounds of iron sulfate per gallon its scale-removing property will have been appreciably reduced. It is at this point that most picklers discontinue adding acid so the acid which remains can be consumed as completely as possible in useful pickling and so that a minimum amount is left to be discarded. To offset both the weakening acid and still accumulating iron sulfate, the bath temperature is gradually raised, eventually to the boiling point, and the bath used as long as it will pickle in a reasonable time. It is then drained. In this way acid strengths can be reduced noticeably and by the careful control of the spent baths, substantial savings in acid can be made.

Inhibitors in Pickling

Pickling in uninhibited acid baths is a wasteful process. In order to remove scale, it is necessary that the acid dissolve some of the underlying metal. Uninhibited acid does not stop dissolving the metal after the scale comes off, with the result that parts of the steel are usually badly overpickled before all the scale is removed. Not only is good metal wasted, but acid is wasted also. It is this waste of both acid and metal that is prevented by inhibiting pickling acids.

Inhibitors localize the attack of the pickling acid and prevent excessive attack on the base metal. This localizing of attack prevents overpickling and burning of the metal. A comparison of the pounds of metal dissolved per unit area pickled in an inhibited versus an uninhibited bath will show the value of inhibitors. On one test the metal loss in an uninhibited bath was 102 pounds in 5 minutes and 390 pounds in 15 minutes. In an inhibited bath, it was only one-half pound in 5 minutes, 2 pounds in 15 minutes, and 5 pounds in 30 minutes. The above samples were pickled in 10 percent by volume sulfuric acid solution at a temperature of 200 F.

When metal dissolves in acid a definite volume of hydrogen is produced. The hydrogen gas when evolved consists of single atoms which quickly combine in groups of two to become molecular or atmospheric hydrogen. The bubbles of molecular hydrogen that form at the surface of the metal in pickling are extremely light. Thousands of them rise rapidly through a poorly inhibited bath. As they reach the surface they break with sufficient violence to throw a spray of pickling acid into the air, contaminating the gas with suffocating fumes that affect the health of the workmen and rapidly corrode any metal work and masonry in the pickling room. To the old pickler, this bubbling was an indication that the bath "was working."

Inhibitors minimize acid fumes by reducing the amount of hydrogen that is formed on the metal surface of the pickled work. Foam-producing grades of inhibitors, in addition to eliminating acid spray, act as insulators and minimize loss of heat from the bath's surface.

By using inhibitors both acid and metal are saved when less metal is dissolved. This is one of the indirect savings often overlooked.

Some of the indirect savings achieved through the use of inhibitors are:

1. Baths are made up less frequently, resulting in lower labor costs in recharging the tanks.
2. The same amount of acid will pickle more metal.
3. Acid fumes are minimized.
4. Corrosion of the buildings and equipment is minimized.

In some respects, pickling with phosphoric acid is preferable to sulfuric acid pickling. The number of tanks required is less than is required in a sulfuric acid pickling system in which rinsing must be more complete. Phosphoric acid is not so corrosive as sulfuric acid under normal conditions of use, and for that reason less expensive construction is possible and less maintenance is required. There are no obnoxious or corrosive strong acid fumes produced which are objectionable to operating personnel.

In the past, phosphoric acid pickling has not been used extensively because the acid itself is so much more expensive than sulfuric acid. However, recently a new process has been developed to reclaim the phosphoric acid pickling solution which now makes it competitive cost-wise with other pickling acids.

Phosphoric acid pickling is normally used prior to phosphate coatings because its residues do not stimulate rust, are easier to rinse and are more compatible with the phosphatizing solutions.

Occasionally, it is advisable to combine both sulfuric and phosphoric acid pickling on the same parts. The sulfuric acid is used to remove the rust and scale. The phosphoric acid is used to rinse away and neutralize the rust stimulators left from the sulfuric acid. The phosphoric acid also leaves a thin iron phosphate coating on the metal surface which offers a good base for a subsequently applied paint film.

Summary

A description has been given of methods for complete removal of such surface contaminants as greases, oils, waxes, rust, scale, and visible and invisible rust stimulators. From the pickling process, the metal is left with a rough etched surface which will give a good mechanical bond to a subsequently applied paint film. This type of bond is good when the service conditions are mild or relatively short life is expected of the paint system.

Phosphate Coatings

If atmospheric conditions are severe and maximum life of the paint system is desired, a chemical bond employing a chemical treatment which forms a surface conversion coating under the paint film is required.

Such treatments, which may require multiple processing steps, extend the life of an organic finish many times. The principal processes used on steel at this time are those which impart a surface conversion coating of insoluble metal phosphates. Phosphate coatings greatly extend the paint life of the finished product in four principal ways:

1. There is improved paint adhesion.
2. The inert crystal coating being non-conductive offers excellent protection against galvanic corrosion by acting as an insulating layer between the paint film and the base metal.
3. There is less creepage of corrosion from scratches in the paint system.
4. There is the use of less paint to achieve longer service life.

These coatings range from heavy, visible crystalline coatings through smooth, hard coatings to microcrystalline coatings. The phosphate coatings are very adherent to the base metal and strong and flexible enough to resist dislodgement under thermal expansion or mechanical deformation in service.

There are two basic types of phosphate coatings: iron phosphate and zinc phosphate. Of the two, the zinc phosphate coatings generally produce the best results and are more widely used. The zinc phosphates are relatively thick, crystalline coatings ranging in weight from 60-4000 mgs/sq feet of surface area. Attempts are made to hold the coating between 150-400 mgs/sq ft when it is used as a pre-paint base. The heavier coatings tend to become brittle and when painted show poor resistance to impact and mechanical deformation. The heavier coatings also become coarser in crystalline structure and absorb much more paint.

The iron phosphate coatings are much thinner, harder and microcrystalline in structure. They have a coating weight range of from 40-90 mgs/sq ft. Since they are thinner, they absorb less paint and a glossy finish can be obtained with less paint.

Zinc phosphate coatings are produced by treating the metal with solutions containing phosphoric acid saturated or supersaturated with the acid zinc phosphate salts. Free phosphoric acid is consumed in small amounts by its attack on the metal surface. This consumption of acid on the metal surface lowers the solubility of the zinc phosphate in the solution causing some to crystallize out on the surface of the metal forming the zinc phosphate coating.

Accelerators such as nitrates, nitrites, chlorates or peroxides are added to the solution to speed up the formation of the coating. They also serve another very important function and that is the control of the ferrous iron build up in the solution. Due to the reaction of the free phosphoric acid with the metal surface, a definite amount of iron is dissolved which goes into solution as ferrous phosphate. Here as in the pickling solutions, the iron gradually builds up to a point where it slows down the formation of the coating and at the same time reduces the quality of the coating formed. At this point it would be necessary to drain and recharge the solution. However with the addition of the accelerators, it is possible to control the buildup of the ferrous iron and extend the life of the bath. The excess iron is precipitated as ferric phosphate which appears as a white sludge and settles to the bottom of the tank.

The process sequence normally involves 5 to 7 stages set up as follows:

1. Cleaning: Oil and grease are removed from the surface of the metal by any one of the conventional cleaning methods.
2. Water rinse: All cleaning residues left on the surface from the cleaning solution are rinsed away.
3. Pickle: All rust and scale are removed.
4. Water rinse: All traces of the acid pickle solution are removed prior to processing. (Stages 3 and 4 may be omitted if there is no rust or scale present on the parts to be treated. However, it is frequently desirable to have two rinse stages after cleaning.)
5. Phosphatizing.
6. Water rinse: The excess phosphatizing solution is removed.
7. Acidulated rinse: Chromic acid or a mixture of chromic and phosphoric acid are used to passify the surface of the coating and neutralize the alkaline salts that would be left on the surface from the water rinse. This rinse leaves the surface on the acid side and helps to ensure maximum paint life.
8. Drying and painting as soon as possible.

The zinc phosphate coating chemicals may be applied by either the dip, spray or brush methods.

Dip Process

The dip process is the oldest and most widely used method. The parts are immersed in a solution at a concentration of 3-10 percent by volume with water and at a temperature of 160 to 210 F. The paint bonding coatings normally have a coating weight of from 150-400 mgs/sq ft of surface area and are formed in two to five minutes.

Spray Process

The spray process is a newer development which has found wide success in industry. Here the solution is pumped from a reservoir and sprayed on the parts through a series of nozzles and then recollected in the same reservoir. The concentration of the phosphatizing solutions used in the spray process is, in general, lower than that used in the dip process. Normally a concentration of 2 percent by volume with water at a temperature of 110-160 F is used. The spray process is used only for the paint-bonding coatings where a coating weight of 150-400 mgs/sq ft is desired.

Brush Process

The brush process is used when it is uneconomical to use the dip or spray methods due to the size, location or number of parts to be treated. The phosphatizing chemicals are diluted with from one to four parts by volume of water and used at room temperature. The dilution ratio is controlled by the temperature and time for application. Normally a time cycle of 1-10 minutes is used to form a coating which has a coating weight of 60-150 mgs/sq ft of surface area. The brush chemicals may be applied with brushes, sponges, rags or may be sprayed with a spray gun or other portable spray equipment.

The foregoing has mainly covered the preparation of steel. However, the same basic principles and practices are employed in treating other metals such as zinc, galvanized iron or aluminum, with the exception that pickling of zinc or aluminum surfaces requires special treatment not covered here.

The advantages of phosphate coatings are being repeated here because of their importance today in the metal-working industry.

These advantages are:

1. There is improved paint adhesion.
2. The inert crystal coating being non-conductive offers excellent protection against galvanic corrosion by acting as an insulating layer between the paint film and the base metal.
3. There is less creepage of corrosion from scratches in the paint system.
4. There is use of less paint to achieve longer service life.

The above advantages are made possible because of the adhesion of the phosphate coating to the base metal, and the fact that the coating is inert and non-conductive. The coating forms as an integral part of the steel surface and in effect converts a portion of the steel surface into the coating itself.

The disadvantages are as follows:

1. More equipment is required to treat the metal.
2. The costs are higher than in the case of other chemical treatments because of the additional steps necessary to process or treat the metal parts.

The chemical cost of a phosphate coating in a spray process is normally 3½ to 8 cents/100 sq ft of surface area processed. In a dip process the cost will range from 5 to 15 cents/100 sq ft.

In the brush process, the cost will range from 50 cents to $1.25 cents per 100 sq ft of surface area. The cost is much higher in this process because the chemicals cannot be collected and reused.

Good, thorough, and complete surface preparation prior to painting is saving industry millions of dollars each year. The cost although sometimes initially higher is much cheaper in the end. This is due primarily to the increased service life of the paint system, which greatly reduces the upkeep and maintenance of the product.

Any discussion of this article not published above will appear in the June, 1957 issue.

CORROSION BY HIGH PURITY WATER

A Symposium

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NOTE: The above-listed papers comprise the entire High Purity Water Symposium given at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 7-11, 1955.

Introduction to Symposium On Corrosion by High Purity Water*

By JOHN F. ECKEL*

Abstract

Information is provided regarding activities and objectives of NACE Unit Committee T-3-F on Corrosion by High Purity Water which was organized at the Association's 1954 annual conference. A brief description is given of the three papers given at the 1955 symposium on Corrosion by High Purity Water.

4.6.5

Introduction

THIS SYMPOSIUM is concerned with an area of corrosion with which some of the members of the National Association of Corrosion Engineers may not be familiar. For this reason and also because the activities of NACE Unit Committee T-3-F are new in the Association, it was felt that a short summary of the activities and objectives of the committee would be helpful.

First, it should be made clear that this area of activity is restricted to high purity water. The term "high purity water" might well have as many different meanings as there are interpreters. For purposes of this symposium it will refer to water that has been distilled and/or deionized so that it will have a specific resistance of 500,000 ohm-cm or greater before the addition of any soluble constituents. This type of water has played an important part in atomic power developments, and consequently, there have been extensive corrosion studies made using it as the corrosive medium.

Those who have been associated with atomic power developments know of the large number of tests that have been made. Most of the data thus obtained are available only in unpublished reports. For this reason it appeared desirable to make available through publication as many of these data as possible, consistent with security regulations. The increasing interest of industry in high purity water justifies this effort.

Committee T-3-F was organized largely through the efforts of D. J. DePaul at the March 1954 meeting in Kansas City. At that time the scope of the committee was defined as follows: "The primary concern of this committee is to provide for the accumulation, correlation and dissemination of all pertinent information which has been developed concerning the corrosion resistance of materials in high purity water." Accordingly, the committee undertook the three following objectives:

1. The preparation of a bibliography.
2. The organization of a symposium for the 1955 meeting.
3. The provision of a working link between the Atomic Energy Commission and industry in general.

Symposium Papers

The present symposium is the realization of one of the objectives of the committee. It consists of three papers. Dr. Roebuck will discuss in his paper some of the results that have been obtained on the corrosion rates of a number of materials in high purity water and also the influence of certain variables. These data are basic and as such are useful in the evaluation of the behavior of different materials when exposed to this type of corrosive medium.

The paper by Mr. DePaul will cover some service tests and experience with high purity water. This includes pilot plant experience involving loops and special components under different conditions such as temperature, composition of water and rates of flow. His data correlated with those of Dr. Roebuck indicate what can be expected in service when certain materials are exposed to the corrosive attack by high purity water.

Mr. Friend's paper will point out some of the industrial uses of high purity water and show how such data as presented by Dr. Roebuck and Mr. DePaul will be useful in the general industrial field.

It is the belief of the committee that the information presented in these papers at this time will serve as a useful contribution to the literature on corrosion. In addition it is hoped that this symposium and the other activities of Committee T-3-F will stimulate further work in the field of corrosion by high purity water.

★ Submitted for publication December 30, 1954.

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TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Corrosion of Structural Materials in High Purity Water*

By A. H. ROEBUCK,[1] C. R. BREDEN[2] and S. GREENBERG[3]

Abstract

Tests were run to determine the corrosion resistance of a number of metals in high temperature, high-purity water. Materials showing the highest corrosion resistance included austenitic stainless steels, precipitation hardening stainless steels, cobalt alloys, platinum, titanium, zirconium and hafnium. Materials of intermediate resistance included aluminum, chromium, 70-30 copper-nickel, ferritic and martensitic stainless steels, nickel and nickel alloys. Test materials showing lowest resistance were copper, bronzes, magnesium, plain carbon steels and silver.

Of the factors affecting corrosion, the system temperature, the system gas concentration (particularly with respect to dissolved oxygen) and the metal surface are of importance. Techniques which can be used to prepare metal surfaces are discussed and compared. Data are given for machined and vapor blasted specimens exposed for 500-1500 hour periods to moving water of various oxygen concentrations.

4.6.5

Introduction

THE SUBJECT of corrosion in high purity water is one which has received a considerable amount of attention within recent months. The interest in this field of research is readily understandable when one considers the recent advances made in the preparation and maintenance of high-purity water systems. A great deal, but not all of this interest has been fostered by work within the Atomic Energy Commission. Many atomic reactors require high-purity water. Most of these systems operate at elevated temperatures.

Much corrosion testing research has been carried out in such systems. A number of reports and papers have been presented on the subject.[1,2,3,4] These reports have by no means exhausted the subject, and have in fact more probably presented only some of the major conclusions of the work conducted. Many other papers should be forthcoming in the future.

This paper will present, in abbreviated form, a description of the corrosion screening tests carried out at the Argonne National Laboratory by the Reactor Engineering Division. A table summarizing some of the general trends of the data also is presented. In addition, the effect of surface condition and surface films on corrosion resistance will be discussed.

Description of Equipment

The equipment used in these tests has been described in other reports.[2] Briefly, it consisted of high-pressure stainless steel test equipment. Autoclaves of the type shown in Figure 1 were used for the standard screening tests. This equipment was constructed entirely of AISI types 347 or 304 stainless steel. Even the gasket ring, as shown in Figure 1, was constructed of stainless steel. A satisfactory seal at working temperatures and pressures was obtained with this gasket.

Structural materials passing the autoclave screening tests were further tested in flowing or "dynamic systems." A schematic diagram of such a system is shown in Figure 2. These systems were also constructed of AISI types 347 or 304 stainless steel. In the dynamic test systems, high temperature, high-purity water was pumped past the sample face at rates of up to 30 feet per second. Lower velocities were obtained in the quasistatic legs of the system.

The water used in these tests was purified by distillation and subsequent deionization in a mixed, strong anion—strong cation, resin bed. The water prepared in such a manner had a specific resistance of 1,000,000 ohm-centimeters or more. The purity of the water was not continuously maintained in the small autoclave screening tests. Those materials which showed high corrosion resistance did not contaminate the test water to an appreciable extent during the test. In the subsequent dynamic tests run in a circulating system, the purity of the water was maintained by use of a cold, partial bypass leg, containing a mixed bed ion exchange resin. The flow through this cold leg was only a small portion of the total flow of the system. The rate of flow through the cold leg was controlled by the necessary valving.

Corrosion Measurement and Evaluation

The corrosion resistance of the materials studied was determined by weight change measurements and specimen appearance changes. The specimens were usually weighed without cleaning or descaling. In several instances, specimens were desealed and cleaned. Weight loss measurements taken on the

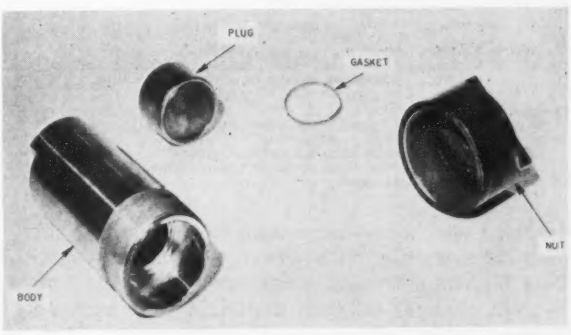


Figure 1—Autoclave equipment used for Argonne static tests.

★ Submitted for publication June 1, 1956.

(1) Continental Oil Company, Development and Research Department, Ponca City, Oklahoma.

(2) Argonne National Laboratory, Reactor Engineering Division, Chicago, Illinois.

(3) Argonne National Laboratory, Metallurgy Division, Chicago, Illinois.

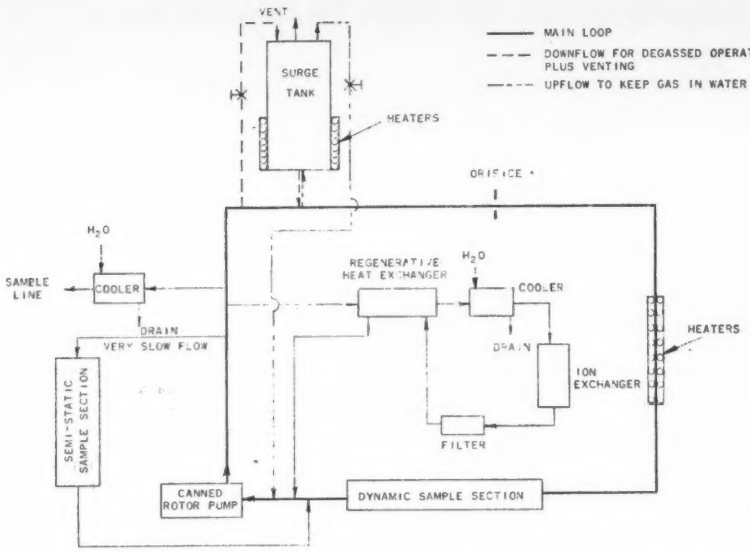


Figure 2—General flow diagram for Argonne National Laboratory dynamic corrosion loops.

TABLE 1—General Corrosion Resistance of Metals in Water[1]

MATERIAL	CORROSION RESISTANCE[2] 200 F	300 F	400 F	500 F	600 F	680 F
1. Aluminum	A	A	V	C	C	C
2. Chromium Plate	A	A	A	B	C	C
3. Cobalt Alloys	A	A	A	A	A	A[3]
4. Copper	A	A	C	C	C	C
70-30 Copper-Nickel	A	A	A	A	C	C
Bronze	A	A	B	C	C	C
5. Hafnium	A	A	A	A	A	A[3]
6. Magnesium	B	C	C	C	C	C
7. Nickel	A	A	A	B	C	C
8. Nickel Alloys:						
Monel	A	A	A	A	B	C
Inconel	A	A	A	A	B	C
Hastelloy	A	B	C	C	C	C
9. Platinum	A	A	A	A	A	A[3]
10. Steels:						
Carbon	B	B	B	B	C	C
Stainless:						
Austenitic	A	A	A	A	A	A[3]
Ferritic	A	B	B	C	C	B
Heat Resisting	A	A	A	A	A	A[3]
Martensitic	A	A	B	C	C	B
Precipitation Hardening	A	A	A	A	B	C
11. Silver	A	B	B	C	C	C
12. Titanium	A	A	A	A	A	A[3]
13. Zirconium	A	A	A	A	A	A[3]

[1] Dissolved oxygen concentration: about 1 ml/l

[2] Symbol Explanation:

A—Highest Resistance
Appearance: No apparent corrosion products: clean tarnish film.
Weight Change: Less than 0.3 mg./(cm²) (mo).

B—Intermediate Resistance
(1) Appearance: No apparent corrosion products; clean tarnish film.
Weight Change: Greater than 0.3 mg./(cm²) (mo).
or: (2) Appearance: Some apparent corrosion products on surface or moderate amount of pitting and spalling.
Weight Change: Less than 0.3 mg./(cm²) (mo).

C—Low Resistance
Appearance: Heavy deposit of corrosion products on surface, or general deep pitting and spalling.
Weight Change: Greater than 0.3 mg./(cm²) (mo).

[3] Recent tests show that these materials have satisfactory corrosion resistance in 750 F superheated steam.

descaled specimens were used in calculating corrosion rates. Primarily, however, only materials of the very highest corrosion resistance were being sought. Weight changes on such materials were very small or negligible before or after descaling. That is, highly corrosion resistant metals, such as the AISI 300 series steels, did not show appreciable weight changes. The appearance of these materials was the primary criterion for evaluation. Less corrosion resistant materials showed greater weight changes and were evaluated largely by weight change criteria.

Results of Test and Discussion

Results of some of the corrosion tests performed are summarized in Table 1. Metals are grouped according to basic composition variations, with each group representing one or more metals of related composition. In instances where more than one metal is included in the group, the relative corrosion resistance rating applies to the group as a whole and not necessarily to any specific metal in the group. The table is intended only to indicate the general range of corrosion resistance of a metal. Extrapolation of the data in this table to a specific metal under specific conditions in a given system is, therefore, not recommended. Such data should be obtained by further testing.

Metal Classes

Several of the classes of materials tested and referred to in Table 1 are broken down into specific metals in the following lists. Metals are listed by their trade names for ease of recognition. Metals not listed, having compositions similar to those listed, may be assumed to have similar corrosion characteristics. The data presented should not be construed to recommend given metals in preference to others. A more complete tabular listing of metals tested, with composition tables, may be found elsewhere.[1]

Cobalt Alloys: Haynes Alloy 25, Stellites 1, 3, 4, 6, 12, 19, 21, 42 and 98M2.

Copper Alloys: Ampco Alloys A-3, 8, 15, 18, 18-23 and 45; Barium B-4, B-8; Lead Bronze; Navy Bronze; SAE 62 Bronze; and 70-30 Cupro-Nickel.

Nickel Alloys: Alnico VI, Ceco "100" Metal, Chlorimet Alloys 2 and 3, Colmonoy Alloys 4, 5 and 6, Durco D-10, Hastelloy Alloys A, B, C and D, Illium C-1, Illium R, Inconel, Incoloy, Inconel X, Monel, K-Monel, S-Monel, Dura-Nickel.

Stainless Steels:

1. Austenitic: AISI Types 302, 302B, 303, 304, 304L, 305, 309, 310, 316, 316L, 318, 321, 329, 347, TS-347A.
2. Ferritic: AISI Types 405, 406, 430, 442, 443, 446.

3. Heat Resisting: Special high alloy steels such as Carpenter No. 7, Fahralloy, C-1, Cyclops Alloys, etc.
4. Martensitic: AISI Types 403, 410, 414, 420, 431, 440A, 440B, 440C, 501.
5. Precipitation Hardening: Armco 17-4 PH, Armco 17-7 PH, USS Type W.

Factors Involved in Corrosion Resistance

Many factors must be considered in any specific corrosion problems. Factors related to the corrosiveness of the system include:

1. Temperature
2. Pressure
3. Water purity
4. Dissolved gas concentration
5. Velocity past the sample face

Factors related to the corrosion resistance of a metal include:

1. Surface condition
2. Heat treatment
3. Amount of metal working
4. Degree of galvanic coupling
5. Geometry of test sample
6. Stress level imposed upon the sample

Because of the voluminous amount of corrosion test data, a complete discussion of each of the factors itemized above is impossible. For this reason, one of the more pertinent items was chosen and will be discussed in detail.

Corrosion Resistance versus Surface Condition

Corrosion is, of course, a phenomenon which takes place at the surface. The condition of the surface prior to corrosion, and the condition of the surface developing during corrosion is very important.

In preparing a metal surface for use, homogeneity is desired. Surfaces free from inclusions and other imperfections which lead to composition variations from point to point across the surface give maximum corrosion resistance. Surface homogeneity reduces initial galvanic effects and localized corrosion to a minimum.

Surface smoothness also is desirable. Surfaces containing crevices or holes have not only a larger surface area, increasing overall corrosion, but tend toward concentration cell or differential aeration attack.

A metal surface may be prepared by any one of several techniques. A number of the more used techniques are listed below:

1. Sand blasting
2. Wire brushing
3. Machining
4. Chemical treatment
   a. Pickling
   b. Anodizing
   c. Other
5. Vapor blasting

The treatments found to give greatest resistance in high temperature water were clean machining and pickling. Clean machined surfaces, prepared by taking small cuts with a sharp tool, give good results. The size of the cut depended on the hardness and toughness of the metal. Overheating and/or surface slurring caused by taking too large or rapid a cut, resulted in decreased resistance.

Acid pickling also resulted in surfaces of high corrosion resistance. The choice of the pickle composition and procedure depended upon the metal. A nitric acid-hydrofluoric acid pickle gave good results with many of the stainless steels and cobalt alloys. The purpose of such a pickle was to remove surface contaminants and a thin outer layer of metal. It was not intended to build a heavy oxide coat, such as might be expected to form in a nitric acid solution or by anodization treatment. The metal was removed from the pickle solution, washed and dried in air. The freshly pickled surface formed a very protective, but thin, oxide layer when exposed to air.

Sand blasting is a well-known and widely used surface preparation technique. It dulls and greys the surface, and in high temperature water decreases the initial corrosion resistance of most metals.

Vapor blasting is a technique in which fine sand or abrasive is blasted against a surface in combination with air and water vapor. This process, as contrasted with sand blasting, results in much lower surface temperatures during surface preparation.

TABLE 2—Rate of Weight Change
(Mg/cm²/month)

Material	Time Hours	0.2 Ml O_2/Liter		2 Ml O_2/Liter		Degassed	
		Machined	Vapor Blasted	Machined	Vapor Blasted	Machined	Vapor Blasted
347 Ta Cb	500	....	....	—.09	....	....	....
	500	....	....	+.02	....	....	....
	1,000	....	....	—.04	....	....	....
	1,000	....	....	—.04	....	....	....
	1,500	....	....	—.04	....	....	....
347 Ta Cb (Welded)	500	—.41	—.78	—.01	....	—.09	—.33
	500	....	—.71	....	....	....	....
	1,000	—.50	—.46	.00	....	—.04	—.17
	1,500	—.39	....	.00	....	—.04	—.13
347 Low Ta	500	—.44	....	+.03	....	—.06	....
	1,000	—.51	....	+.01	....	—.04	....
	1,500	—.40	....	+.01	....	—.03	....
316	500	....	—.85	....	+.02	—.04	—.35
	500	....	—.74	....	....	....	—.34
	500	....	—.75	....	....	....	....
	1,000	....	—.48	....	—.01	....	—.17
	1,500	....	....	....	....	....	—.11
304 ELC	500	+.01	—.75	+.04	+.03	....	—.21
	500	....	—.78	....	+.01	....	....
	1,000	....	—.47	....	+.04	....	+.09
	1,500	....	....	....	....	....	—.06

NOTE: Water velocity 30 feet per second.

Sand blasting may produce badly scorched or oxidized areas if not properly performed. Table 2 illustrates the variation in corrosion resistance of machined and vapor blasted specimens. Although vapor blasting is not as deleterious to surface resistance as sand blasting, it is more deleterious than machining procedures.

Wire brushing techniques are recommended only for removing heavy scale or rust. They should be used as more of a preliminary clean-up rather than as a final surface preparation. Wire brushing results in high surface temperature and worked metal in the surface. Both of these factors are undesirable in surface preparation techniques.

Conclusions

Long term corrosion exposures minimize initial effects due to surface preparation. However, low initial corrosion resistance may initiate other undesirable forms of corrosion such as pitting or cracking. For this reason, and also in order to reduce system clean-up requirements, good surface preparation techniques are desirable. The ability of some metals to form, and maintain (and also to repair) protective films depends on the elimination of surface contaminants. For example, the presence of iron (as a residue from machining operations) might prevent, or at least impair, the formation of a film on stainless steel. It is thus desirable that the surface preparation leave the metal free of any contaminant to which it is vulnerable.

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1. C. R. Breden, S. Greenberg, A. H. Roebuck, et al. Argonne National Laboratory Report ANL-4519, Progress Report I, Water Corrosion of Structural Materials, July 15, 1951.
2. C. R. Breden. National Association of Corrosion Engineers Short Course in Corrosion, University of California, Berkeley, California, 1953.
3. A. H. Roebuck. Fifteenth Annual Water Conference of the Engineers Society of Western Pennsylvania, October, 1954.
4. D. J. DePaul, et al. Westinghouse Atomic Power Division, Topical Reports.

Any discussion of this article not published above will appear in the June, 1957 issue.

Corrosion Engineering Problems in High Purity Water*

By D. J. DePAUL

Introduction

THE PRECEDING paper presented by Dr. Roebuck provides a good general picture of the materials normally considered suitable with respect to corrosion in high temperature water. The evaluations made by Dr. Roebuck were based entirely on the inherent corrosion resistance of materials in several well defined controlled environments. This type of information is extremely valuable in making the initial choice of materials for equipment exposed to corrosive environments; however, there are many specific corrosion problems which result from "unexpected," "abnormal" and transitory environments which are directly related to the engineering application of the material. The present investigation deals with these types of corrosion problems and covers, in a summary manner, some of the more important application problems relating to crevice corrosion, galvanic corrosion, stress corrosion and intergranular corrosion.

Unless otherwise indicated, all evaluations and remarks made pertaining to the suitability of materials are based on exposure to high purity water at temperatures between 500 and 600 F and at velocities up to 30 feet per second. High purity water is defined as water having a total solids content of less than 1 ppm and a resistivity of at least 500,000 ohm-cm. Normally, oxygen contents were between 5 and 10 cc per kilogram of water (STP).

Crevice Corrosion

One of the important corrosion problems associated with materials in contact with high purity, high temperature water is crevice corrosion, about which there is very little information in the published literature. This form of corrosion has been a problem of major concern in the design considerations and the choice of materials for water cooled reactor components. Under the conditions of testing with which the author is concerned (i.e., in high purity water at temperatures up to 650 F) the mechanism of attack has been fairly well established as an oxygen concentration cell. Crevice corrosion is undesirable because it produces relatively large amounts of corrosion product at the mouth of a crevice which, in applications involving moving parts with small clearances, may cause excessive wear or complete seizure.

Figure 1 illustrates the form in which this type of corrosion normally occurs. This is a standard contact corrosion test sample and is shown disassembled in order to reveal the location and extent of buildup of the corrosion product. It can be seen that a narrow ridge of corrosion product has formed at the perimeter of the contact area which outlines the position of the sleeve in the assembled couple. It also should be noted that little or no corrosion has occurred within the crevice area. This is very characteristic in the type of crevice corrosion experienced by the author.

The materials situation with respect to crevice corrosion is summarized in Table 1. It can readily be seen that all of the major groups of materials studied are susceptible to crevice corrosion. The extent of buildup at the perimeter of the contact area normally decreases with increasing corrosion resistance of the material. Certain materials, namely the straight chromium stainless steels, high copper and high nickel alloys, are subject to pitting on the area in contact. This type of pitting does not result from any possible galvanic effects, inasmuch as it occurs with couples made up of the same materials and with these materials in contact with plastics. The pitting observed is usually minor in nature and is normally of no real consequence except in moving parts with close clearances. Pitting has been observed with these alloys at temperatures as low as 200 F.

Figures 2 and 3 illustrate the effect of temperature, oxygen content and clearance on crevice corrosion. Although most of the work was done on the more corrosion resistant materials, such as the 18-8 type stainless steels, the information applies to most

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Abstract

The paper describes some of the important corrosion problems encountered in systems exposed to recirculating high purity water with respect to the particular engineering application of materials. Special attention is given to crevice, galvanic, intergranular and stress corrosion as a function of the various materials studied. Materials considered include 18-8 type stainless steels, cobalt base alloys, hard chromium plate, copper base alloys, nickel base alloys and straight chromium stainless steels. Data are given to show the effect of oxygen and clearance on crevice corrosion at 500 F. Also shown is the effect of temperature on crevice corrosion in oxygen-bearing water. 4.6.5



Figure 1—Example of crevice corrosion.

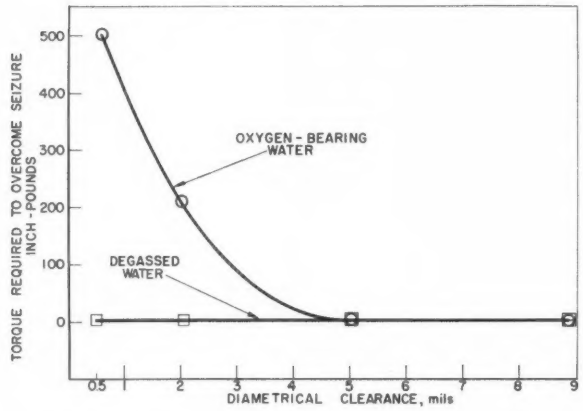


Figure 2—Effect of oxygen and clearance on crevice corrosion at 500 F.

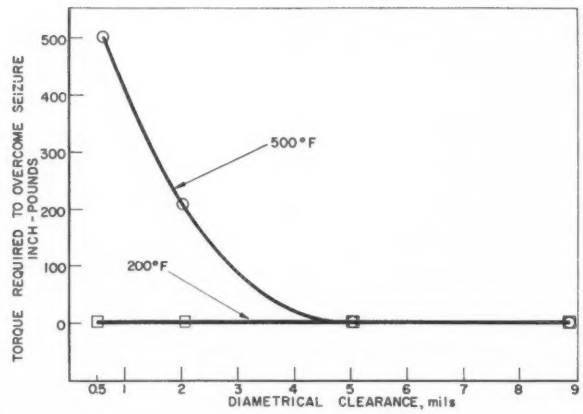


Figure 3—Effect of temperature on crevice corrosion in oxygen-bearing water.

of the materials studied. Figure 2 shows that this form of crevice corrosion is dependent on oxygen and that the bad effects of oxygen can be tolerated if clearances are maintained in excess of 5 mils. Figure 3 illustrates the effect of temperature on crevice corrosion. At the lower temperature there is essentially no problem of crevice corrosion, especially with the more corrosion resistant materials. Normally, the extent of contact corrosion found at 200 F amounts to nothing more than a discoloration of the metal without any measurable build-up.

It can be seen that it is essential during the design stage to consider such items as materials, clearance in moving parts, extent of movement, temperature and oxygen content of the water. Permanent crevices formed by such items as threaded joints and flanged or socket weld joints are of no practical concern, since the amount of metal lost is exceedingly small and the corrosion build-up formed at the mouth of the crevice does not produce any harmful effects.

Pitting in Crevices

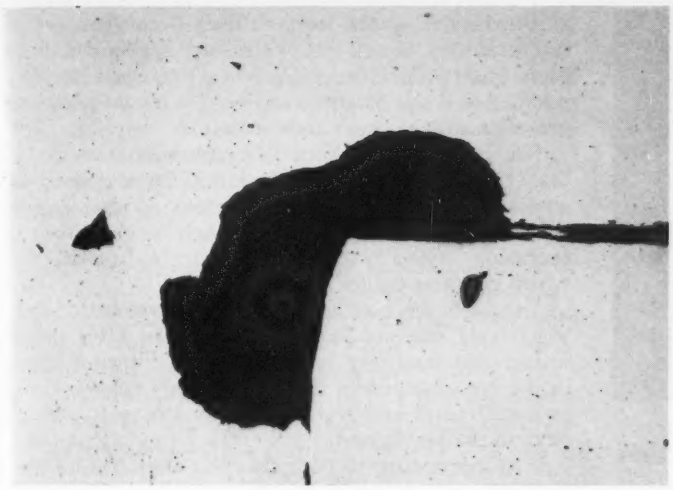
Attention so far has been directed toward the importance of build-up, but it should be pointed out that there are certain applications where pitting in crevices is more important than build-up of corrosion products. For instance, the use of stainless steel Type 410 as a rivet material is generally considered a good choice because the material does not work harden readily. It is not considered good practice, however, in the applications under discussion because crevice corrosion pitting proceeds along the length of a rivet at a fairly rapid rate. Penetration rates in the order of 70 mils per year have been observed in water at temperatures between 200 and 500 F.

Figure 4 shows the extent of attack which occurred in rivets exposed to temperatures of 200 and 500 F for two months. This problem was solved by using a special high chromium and nickel stainless steel, Carpenter No. 10, having desirable riveting properties and which was not susceptible to accelerated corrosion within the crevice.

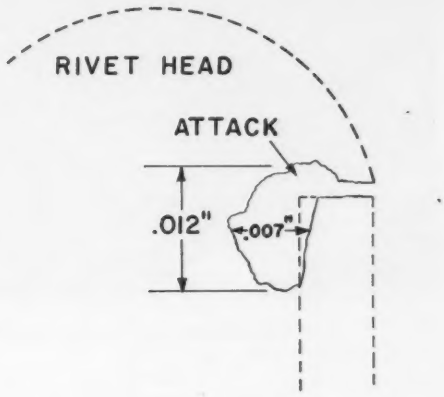
Accelerated attack in crevices also has been a problem with plain ground springs where the last turn forms a crevice with the supporting structure. Unfortunately, many of the materials having good spring properties are in the group of materials that

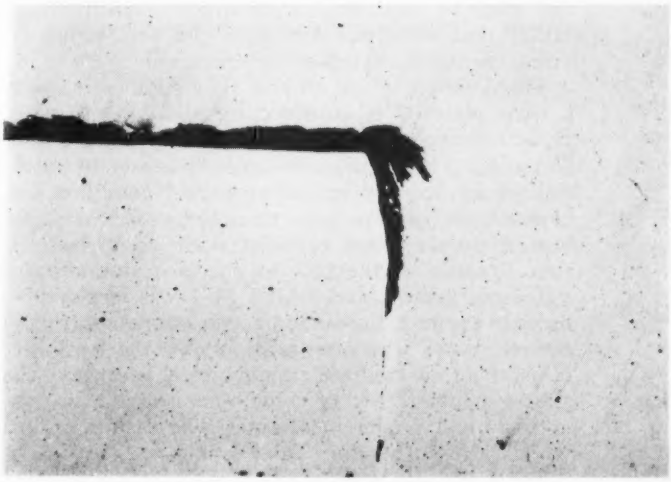
TABLE 1—Susceptibility of Various Materials to Crevice Corrosion

MATERIALS		Type of Attack
Groups	Investigated	
18-8 Type Stainless Steels	AISI 302, 304, 316, 321, 347	Corrosion Buildup
Cobalt Base Alloys	Stellites 1, 3, 6, 12, 19, 21, 24	Corrosion Buildup
Hard Chromium Plate		Corrosion Buildup
Copper Base Alloys	Brass, Bronze, 70-30 Copper-Nickel	Corrosion Buildup and Pitting
Nickel Base Alloys	Inconel, Inconel "X", Monel	Corrosion Buildup and Pitting
Straight Chromium Stainless Steels	AISI 410, 420, 430, 431, 440	Corrosion Buildup and Pitting



500 F—50 days





200 F—60 days

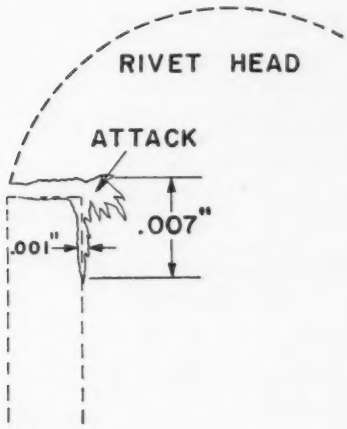


Figure 4—Crevice corrosion in rivet applications.

exhibit pitting. Therefore, for lack of a better material, it was necessary to plate the flat ends of the last turns with chromium which is not susceptible to pitting under these conditions. In this application, corrosion buildup in crevices is not important.

In connection with the accelerated attack observed in crevices, an interesting case has been observed as shown in Figure 5. There severe intergranular attack was observed only on those surfaces of the metal exposed to the crevice, whereas the remaining surface was not attacked in this manner.

Activation of mechanical parts by magnetic control is another application in which crevice corrosion is an important consideration. The bad effects of crevice corrosion, in this case, are shown schematically in Figure 6. With this type of arrangement mechanical movement can be actuated within a water system without any external seals by energizing or de-energizing the coils. Both corrosion buildup and pitting increase the air gap between the coils and the armature, which in turn may cause the mechanism to release at a value below the calculated holding force.

Although the information presented here on crevice corrosion was based on studies conducted in high purity water, there are indications that much of the data are applicable to general industrial water problems, especially in boiler plant systems.

Generally speaking, dissimilar metal contacts do not show evidence of preferential accelerated corrosion in high purity water. This has been found to be true even with carbon steel welded to stainless steel where there was a considerable difference in the nobility of the metals. The explanation for the lack of occurrence of galvanic corrosion is thought to be due to the high electrical resistivity of the water which serves to interrupt any galvanic currents which might normally exist at a lower resistivity level. In this connection, it is interesting to note that a soil resistivity of 10,000 ohm-cms is generally thought to be sufficiently high to prevent major galvanic corrosion problems with underground pipe lines.

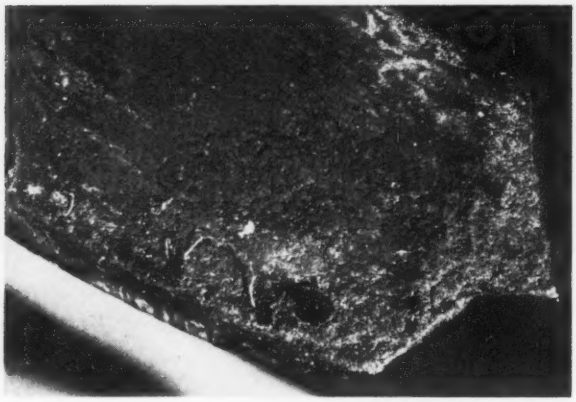


Figure 5—Crevice corrosion in spring applications.

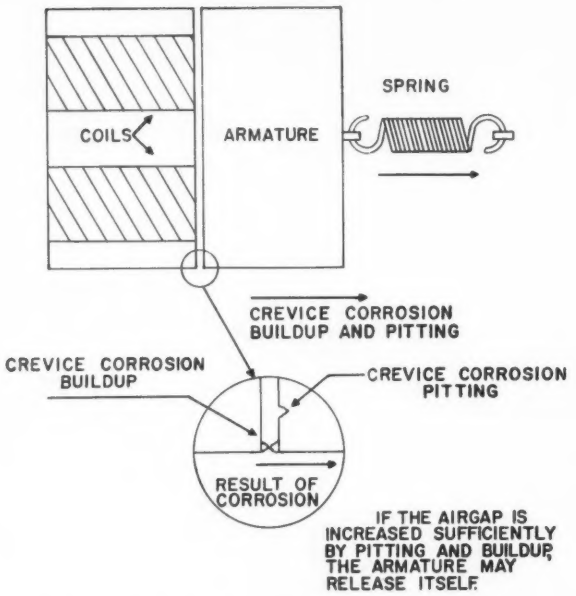


Figure 6—Effect of crevice corrosion on armature applications.

Spring Materials

Most of the information on stress corrosion in high purity water developed in this investigation was obtained in the search for suitable spring materials having high corrosion resistance. Consequently, the data presented are not representative of an organized study on the general problem of stress corrosion, but rather are the result of an empirical investigation in which only pertinent variables expected in service were studied.

Table 2 summarizes the materials situation with respect to stress corrosion. Note in the last column that most of the materials studied were not suitable for spring applications. As a matter of fact, if one considers and weighs all of the factors involved in choosing a good spring material, there is only one suitable material—Inconel "X". Stainless steel cannot be used because in the cold-worked form it is susceptible to stress cracking. Although Inconel is not subject to stress cracking, it is not normally used at the higher water temperatures because cases of intergranular attack in unstressed specimens have been observed. This subject has not been actively pursued and the exact conditions under which intergranular attack occurs are not known.

The International Nickel Company has suggested that the mechanism of attack on Inconel may be similar to that of intergranular attack on unstabilized austenitic stainless steels, inasmuch as this form of corrosion normally does not occur in Inconel "X" which contains columbium.

Although the highly cold-worked austenitic stainless steels are subject to cracking in high purity water, this tendency has not been a limiting factor in the use of stainless steel (not highly cold-worked) as a structural material even when stressed to levels beyond the yield point.

It is interesting to note that the amount of corrosion normally associated with stress corrosion cracking of these materials is extremely small and barely discernible. This suggests the possibility that cracking may be initiated by hydrogen embrittlement rather than by stress corrosion per se. Studies on stress corrosion are still being continued.

The decision to use an 18-8 type stainless steel as a basic material of construction raised many questions concerning its susceptibility to intergranular corrosion. These questions arose because the material would be used in the as-welded condition and exposed to various heat treatments which would precipitate chromium carbides at the grain boundaries. Because of the lack of specific information a stabilized stainless steel (AISI 347) was employed in order to ensure against intergranular attack occurring in service. Work was done to determine the feasibility of using an unstabilized stainless steel because of the strategic importance of columbium and the savings in costs and procurement time. The results of this work are summarized in Table 3.

Table 3 shows that the types of waters with which the author is concerned are not sufficiently aggressive to cause intergranular attack of unstabilized stainless steels in the as-welded or sensitized condition. The study included carbon contents as high as 0.25 percent in order to determine if any danger of attack exists in the event that carburizing accident-

TABLE 2—Susceptibility of Various Materials to Stress Corrosion Cracking

MATERIALS		Conditions	Susceptibility to Stress Corrosion
Type of Alloy	Materials Studied		
Austenitic S.S.	AISI 304	Stressed Beyond the Yield Point	No
	AISI 304	Cold-Worked 60-90 Percent for spring hardening. Stressed to 20,000 p.s.i.	Yes
Ferritic S.S.	AISI 410	Spring hardened. Stressed to 60,000 p.s.i.	Yes
	AISI 431	Same	Yes
	Armco 17-4 PH	Same	Yes
	Armco 17-7 PH	Same	Yes
	USS 18-8W	Same	Yes
Cobalt Base	Elgiloy	Same	Yes (?)
Nickel Base	Inconel	Spring hardened. Stressed to 70,000 p.s.i.	No
	Inconel "X"	Same	No

ally occurs during fabrication and heat treatment of a piece of equipment.

It is realized that considerably more time could be spent on the various subjects of this paper. However, in view of the limited time available, it was considered more desirable to present the summarized data with a minimum amount of discussion.

Acknowledgment

The author acknowledges the contributions made by A. Squire, E. M. Reno, R. Stein, J. W. Barbour, and J. G. Christ, of the Westinghouse Atomic Power Division, and expresses his thanks for their supervision and assistance in carrying out various phases of the work. Work described in this paper was performed under a government contract with the AEC AT-11-1-GEN-14.

DISCUSSION

Question by L. W. Vollmer, Gulf Research and Development Company, Pittsburgh, Pennsylvania:

In stress corrosion cracking tests was the amount of austenite decomposition of cold worked stainless Type 304 determined? If so, did cracking susceptibility relate to amount of phase change?

Reply by D. J. DePaul:

The amount of ferrite formed was not determined; however, when the material was cold reduced above 30 percent, the susceptibility to stress cracking was materially increased.

Question by Norman D. Groves, General Electric Company, Richland, Washington:

What was the object of the 24 hour 1200 F heat treatment used in your summary table? Normally it is considered sufficient to heat treat stainless steel for two hours at 1200 F if the purpose of the heat treatment is to "sensitize" or precipitate the carbides into the grain boundaries.

Reply by D. J. DePaul:

It has been demonstrated that the suspectibility of an unstabilized 18-8 type stainless steel to intergranular attack increases with the time of exposure to the sensitization temperature up to several thousand hours. In some of our applications, structures were large enough so that weldments could conceively be in the sensitization range for periods as long as 24 hours. Consequently, this period was chosen on the basis that it would be the worst case expected. For most applications, however, two hours will be sufficient to duplicate temperature conditions resulting during fabrication.

TABLE 3—Summary Data on the Susceptibility of Austenitic Stainless Steels to Intergranular Corrosion

MATERIAL CONDITIONS STUDIED (18-8 S.S.)		Corrosion Test Conditions (3 Months Duration)	Results
Percent Carbon	Heat Treatments		
0.03 0.05 0.10 0.15 0.20 0.25	2 hours at 1200 F 24 hours at 1200 F Solution Annealed	(a) 640 F Water (neutral pH) (b) 600 F water (pH 3-4) (c) 600 F water (pH 10-11)	No attack in (a) and (c). Slight intergranular attack in (b) on sensitized steels at the higher carbon contents.

Comment by A. H. Roebuck, Continental Oil Company, Ponca City, Oklahoma:

My question applies to the mechanism of the corrosion reaction within the crevice you describe. Since the total amount of corrosion occurring in the crevice is not limited to the amount of oxygen originally present in the crevice, and since diffusion of oxygen from the system into the crevice can be calculated to be slow, the mechanism describing the corrosion reaction must involve anodic depolarization by corrosion products. It is true that the reaction is no doubt started by the presence of oxygen, but upon oxygen depletion, the reaction is continued by reaction of water and iron at the anode, and reduction of hydrogen at the cathodes.

Reply by D. J. DePaul:

Unfortunately, the subject of crevice corrosion in stainless steel has not been thoroughly investigated from a fundamental point of view. It is quite possible that we are dealing with an active passive cell; however, the strong dependence of this form of corrosion on oxygen together with some indication that the reaction tends to stifle itself, would suggest an oxygen concentration type of cell.

Question by L. C. Oseland, Carpenter Steel Co. —Tube Division, Kenilworth, Illinois:

Since you stated Carpenter No. 10 corrected rivet corrosion problems, would Carpenter No. 10 be superior in tubular form in heat exchangers to the 300 series which were satisfactory but showed corrosion build-up?

Reply by D. J. DePaul:

Carpenter No. 10 and the 300 series type stainless steels show the same susceptibility to corrosion buildup in crevices. In this connection, we are concerned primarily with the comparison of Carpenter No. 10 stainless steel with stainless steel Type 410. The latter material is very susceptible to pitting within crevices whereas the former is not. All materials show corrosion buildup at the perimeter of the crevice. In rivet applications, buildup is not considered detrimental, whereas pitting could loosen a rivet.

Question by R. B. Mears, Applied Research Laboratory, United States Steel Co., Monroeville, Pa.:

In the crevice corrosion tests, how was the ring centered on the rod?

Reply by D. J. DePaul:

No special effort was made to center the sleeve (or ring) on the journal (or rod). However, the sleeve was wired to the journal in order to prevent

slipping along the axis. Experience has shown that the sleeves aligned uniformly as a result of the corrosion products formed inside the sleeve.

Discussion by Joseph E. Draley, Argonne National Laboratory, Lemont, Illinois:

Mr. DePaul and Dr. Roebuck have discussed at some length and have given data for the corrosion of stainless steels and some related materials in water at elevated temperatures. Perhaps it would also be interesting to you to hear some aspects of the corrosion behavior of aluminum in similar environments. At temperatures up to about 400 F, commercial aluminum alloys corrode in distilled water in a similar manner to that at temperatures below the boiling point. Corrosion rates are generally low and penetration is nearly uniform. Minimum rates of corrosion can be obtained by adjusting the solution pH. As the temperature is increased, the pH of the nearly pure water in which corrosion is minimum decreases.

At temperatures above 400 F, a new phenomenon becomes serious for 2S (1100) aluminum. The temperatures at which the same observation is made for different commercial alloys are somewhat different. Apparently hydrogen produced in the corrosion reaction diffuses into the metal structure, mostly at grain boundaries, and produces pressure pockets internally in the metal. These pressure pockets cause the formation of blisters, which subsequently rupture and let the water into the metal structure. This produces hydrogen and the process is self-accelerating. At temperatures of the order of 600 F, this kind of attack is very rapid and the metal is destroyed quickly.

Two means of preventing the attack are effective: By providing cathode sites for the liberation of hydrogen other than at the aluminum metal surface, and by making the aluminum impermeable to hydrogen diffusion. The latter method appears to be impractical. Although carefully vacuum cast metal does not appear to be susceptible to the blistering attack, it loses its resistance upon metal working.

To provide cathode sites, solutions of certain reducible metal ions can be used instead of distilled water. Among reducible cations, those which produce metals of low hydrogen overvoltage are effective. Nickel sulfate is one such useful solution. Nickel metal deposits at preferred cathode sites on the aluminum and the hydrogen produced in the cathodic part of the corrosion reaction is liberated there. The concentration of the nickel salts required is not high: 5 ppm nickel ion appears to be sufficient to provide complete protection against blistering attack, as evidenced by tests at 527 F. It is necessary to add acid to such solutions to prevent the formation of basic salts and their deposition on heated surfaces.

Aluminum-nickel alloys have been prepared in which the nickel-rich constituent appears largely as a second phase. Samples of these alloys show excellent resistance to blistering attack, presumably by the same mechanism. When alloys are carefully prepared, amounts of nickel in excess of 0.5 percent appear to be sufficient either to stop blistering completely, or to inhibit it to an extent making possible the use of the material in distilled water at elevated temperatures. The maximum temperature to which these alloys can be used depends on the corrosion rate which is tolerable; as the temperature is increased the corrosion rate increases. Samples have shown excellent appearance after exposure to distilled water at temperatures as high as 660 F.

Another method of providing satisfactory protection using nickel is to plate the surface of the aluminum prior to test. "Kanigen" electroless nickel plating has been employed to coat a number of samples, and others have been electroplated. To date, samples coated with several tenths of a mil of nickel in this fashion have withstood corrosion tests of many weeks duration, having rapid flow of distilled water past the samples at a temperature of 600 F.

It now appears that alloys can be made which will not be susceptible to the intolerable hydrogen penetration during exposure to water at elevated temperatures. If subsequent testing bears out this promising indication, aluminum alloys may find considerable application where corrosion resistance to high temperature water is required.

Reply by D. J. DePaul:

Dr. Draley presented an interesting discussion on the possible use of aluminum alloys in water cooled reactor applications. It is realized that considerable improvement in the corrosion resistance of aluminum alloys may be afforded by small alloy additions. However, these alloys were not included in the presentation because, to date, there is no such alloy having the desired corrosion resistance for which well established mechanical data and fabricating techniques are available.

Any discussion of this article not published above will appear in the June, 1957 issue.

The Importance of High Purity Water Data To Industrial Applications*

By W. Z. FRIEND

Introduction

A CONSIDERABLE amount of test data on the corrosion and wear of metallic and non-metallic materials in high purity water has been accumulated during the past six years. This information has been gathered by several laboratories under the supervision of, or under contract with, the Atomic Energy Commission or the U. S. Navy, and other investigators. Most of this work was done primarily to determine the performance of metallic and non-metallic materials of construction in water under the conditions which would prevail when the water was being used as a combined coolant and heat transfer medium in nuclear power plants. In this application the high purity water is considered as the primary heat transfer medium, circulating through the atomic reactor to pick up heat and then circulating through a heat exchanger to transfer this heat to the boiler feed water of a conventional steam power plant. Most of the work was done in water at 500 to 600 F and under pressures up to 2000 psi, although some work was done in water at temperatures as low as 250 F.

A particular requirement of the water in this system is that it be extremely low in dissolved or entrained solids which might, if present, pick up radioactivity in the atomic reactor and transfer this radioactivity to the power plant heat exchanger or to the boiler feed water. Another requirement is that the materials of construction and control devices used to handle this water be free from such corrosion or wear as would introduce objectionable amounts of metallic ions or particles into the water system, or would interfere with the operation of mechanical devices. Obviously these particular requirements would apply principally to nuclear systems such as this. However, it is anticipated that the corrosion and wear data and the service experience gained in the systems now in operation will be of considerable use to other industries and plants which use high purity water for a large variety of non-nuclear applications.

The term "high purity" water probably means something different in every application in which it is used. Most of the test work reported by Roebuck[1] and by DePaul[2] apparently was done in water having an electrical conductivity of 1 to 2 micromho-cm prepared by distillation and deionization. Such water might not be considered really high purity water by certain individuals. This would include the operator of a modern high pressure steam plant who may require water having conductivity of 0.1 to 0.3 micromho-cm for the boiler feed water make-up, or a television tube manufacturer who may require water of the same purity for processing the sensitive coatings on the tubes.

On the other hand, many plants or processes requiring distilled or deionized water consider a maximum dissolved solids content of up to 5 ppm (about 10 micromho-cm conductivity) to indicate high purity water. Doubtless all of these users are concerned about avoiding metallic pick-up by the water after having gone to the expense of eliminating it. The effect of several dissolved electrolytes upon the electrical conductivity of water at 18 C as calculated from ion conductance data given by Glasstone[3] is shown in Figure 1.

Deionization Systems

Water of the purities with which this work is concerned can be prepared by distillation or by deioniza-



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Abstract

The most common industrial use of very high purity water is for boiler feed water in modern high temperature high pressure steam plants. It has industrial uses also in chemical research laboratories, pharmaceutical production, manufacture of color film, manufacture of high resistivity dielectric papers, electroplating, processing synthetic textile fibers, catalyst production and in the application of phosphor coatings in television tubes.

Experience has shown that high purity water is more aggressive than most less pure waters in corrosion of iron and steel, particularly if dissolved oxygen is present. A review of available information on plant experience indicates that corrosion resistant metals such as stainless steels, nickel alloys or aluminum are generally required to handle high purity water. At moderate temperatures non-metallic materials such as rubber and vinyl polymers are often used to avoid metallic contamination. **4.6.5**

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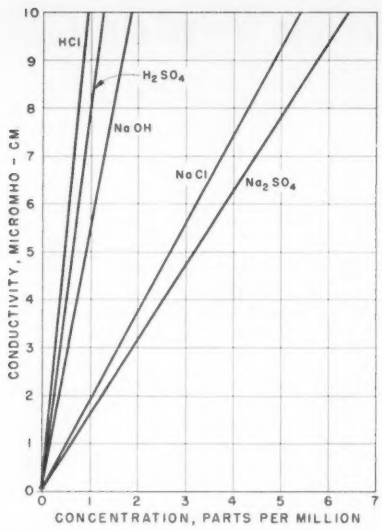


Figure 1—Effect of dissolved electrolyte on the electrical conductivity of water at 18 C.

tion with ion exchange resins. The higher the purity required the more likely it is that deionization will be less costly than distillation, where appreciable quantities of water are involved.

A two-bed resin deionization system with strongly acidic cation exchange resin and weakly basic anion exchange resin and a degasifier or deaerator will generally give an effluent having an electrical conductivity of about 10 to 20 micromho-cm. It may contain dissolved solids equivalent to about 5 ppm calculated as calcium carbonate, in addition to silica.

A two-bed system with strongly acidic cation exchange resin and strongly basic anion exchange resin will give an effluent containing less than 2 ppm dissolved salts, including silica. Carbon dioxide is reduced to zero and silica content to an average of less than 0.1 ppm. Commonly, water produced by this system has an electrical conductivity as low as 4 micromho-cm. Multiple separate bed systems will produce water with conductivity as low as 0.5 micromho-cm., depending upon the combination of resins and number of beds.

Deionization with mixed-bed systems using strongly acidic cation exchange resin and strongly basic anion exchange resin mixed together in the same bed will provide water of the highest quality. This water may be characterized by a conductivity as low as 0.1 micromho-cm and total dissolved salts less than 0.05 ppm with silica content less than 0.01 ppm. Under the most favorable circumstances conductivity as low as 0.05 micromho-cm has been attained. The water is purer than the ASTM requirement for reagent water (D-1193-51T). Comparison with distilled water is given in Table 1.[4]

TABLE 1—Quality of Water Obtained from Various Sources

TYPE OF WATER	Resistance, ohm-cm	Conductivity, micromho-cm
Water after 28 distillations in quartz[1]	23,000,000	0.044
Water treated by strongly acid-strongly basic mixed bed resin (Delaware River water)	18,000,000	0.055
Water after three distillations in quartz	2,000,000	0.5
Water after three distillations in glass	1,000,000	1.0
Water in equilibrium with the carbon dioxide in the atmosphere	700,000	1.4
Water after a single distillation in glass	500,000	2.0
Approximate quality of USP distilled water[2]	100,000-500,000	2.0-10.0
Theoretical maximum quality (calculated)	26,000,000	0.04

[1] Kohlrausch, 1894.
[2] The U.S. Pharmacopoeia specifies that USP distilled water must not contain more than 5 ppm total dissolved solids.

Distillation equipment, if properly operated, delivers a distilled water containing 1 to 2 ppm dissolved solids although in practice commercial distilled water may contain up to 20 ppm dissolved solids as shown in analyses reported by Applebaum and Myers.[6] It is reported that the Kleinschmidt compression distillation units will produce water containing less than 1 ppm dissolved solids.[7]

Boiler Feed Water

The largest use of high purity water, from the standpoint of volume, has been that of boiler feed water for high pressure steam boilers in utility and industrial power plants. To maintain boiler efficiency, it usually is desirable to keep the amount of scale-forming salts at a minimum. In modern high pressure steam plants operating at 1200-1800 psi and higher, the presence of silica in the boiler water is particularly troublesome. At steam pressures, possibly as low as 500 psi and certainly at 1000 psi, the silica in the boiler water volatilizes and passes out with the steam. As the steam expands through the turbine and reaches the intermediate pressure stages, the silica is condensed and deposited on the turbine blades as a hard glassy film. These silica deposits are very difficult to remove and lower the efficiency of the turbine until it finally must be shut down for cleaning.

In order to prevent objectionable silica carry-over, it is necessary to keep the silica content of the water in the boiler at a low level. In order to do this, the silica content of the feed water make-up must be at a very low figure. Many high pressure central stations operate so that feed water make-up requirements are only 0.75 to 1.5 percent. However, in some cities where turbine exhaust steam is used for central heating, make-up requirements will run up to 40 percent and higher. In one large chemical plant operating 1250 psi boilers, all of the exhaust steam is used for processing, requiring 100 percent make-up.[8] Plans are underway for several boiler installations using water under super-critical conditions.

It is estimated that, in order to prevent objectionable silica carry-over, the silica content of water in the boiler must not exceed 5 ppm for a 1250 psi boiler, 3 ppm for an 1800 psi boiler and 1.5 ppm for a 2100 psi boiler.[9] To achieve these low figures, many engineers require make-up water with silica contents as low as 0.01 to 0.05 ppm. In practice such waters are obtained by distillation or by resin deionization using a strongly basic anion resin, accompanied by deaeration.

There are numerous references in the literature to installations of deionization equipment for boiler feed water treatment where the average effluent water contains about 3 ppm total dissolved solids

(about 2 to 5 micromho-cm conductivity) and less than 0.2 ppm silica. Forty[10] referred to a power plant making 1800 psi steam where the water delivered to the boilers had total dissolved solids of 0.2 to 0.3 ppm, maximum silica of 0.12 ppm and conductivity of 1 micromho-cm. Dick[11] described the installation at a power plant making 1800 psi steam and having high make-up requirements where the deionization equipment normally produced water of 0.1 micromho-cm conductivity. Silica content normally was less than 0.01 ppm.

Other Uses of High Purity Water

There are numerous other users of distilled or deionized water of high purity, all of whom have the problem of handling this water during their processing operations. A partial list of industries and/or processes now using deionized water, as obtained from Nordell[12] and other sources, is given in Table 2. This list no doubt is incomplete at the present time and is continually expanding with the demand for processing improvements. A review of some of the published information, and discussions with manufacturers of deionization equipment reveals the following miscellaneous information about some of the water purity requirements.

Research Laboratories

Many large research laboratories use considerable amounts of demineralized water with maximum conductivity of 1 micromho-cm. In some cases distilled water, free from organics, also is required. Skold and Wilkes[13] described the installation of a mixed bed demineralization plant at a large university laboratory. During 95 percent of the service run it provides water with conductivity of about 0.06 micromho-cm and cuts off for regeneration at 1 micromho-cm.

Television Tubes

Most manufacturers of television tubes require high purity water for the settling and washing of phosphor coatings on tubes.[14] Minute traces of salts in wash water may cause streaking of the phosphor. The water is demineralized by ion exchange, some plants having a cut-off of 1 micromho-cm. The presence of dissolved gases in the water may cause bubbles in the phosphor coating so that deaeration treatment also may be given.

High purity water is used for cooling vacuum power tubes in some radio stations. Apparently the temperature rise of the water can be used to measure the power output of the station. Some ultra high frequency heating tubes are cooled with high purity water. Such water is used in the production of transistors.

Pharmaceutical Production

There are many uses of high purity water in pharmaceutical manufacturing plants such as the purification and washing of chemicals, the preparation of patent medicines, drugs and antiseptics, and the washing of ampules. References[15,16] indicate the use of deionized water at such plants. In one case the water had a total dissolved salt content of 9 ppm including silica and in another case it had 3 ppm dissolved salts other than silica. The specifications of USP water call for a maximum of 5 ppm total dissolved solids and this is probably sufficient for most purposes.

Photographic Industry

High purity water is required in the photographic industry in the production of film paper and gelatine and in film processing.[17] For most purposes, however, the conductivity does not need to be less than 2 micromho-cm. Lindsay[15] makes reference to a plant producing water containing less than 5 ppm dissolved salts in addition to silica for use in the mixing of colors and dyes in the manufacture of color films for the motion picture industry. Duplicability of colors is of utmost importance and high grade water eliminates the possibility of "off shades" resulting from the water used. High purity water is used for washing high precision lenses.

Pulp and Paper Industry

The pulp and paper industry has use for high purity water in the production of certain high quality papers and cellulose. While much of it does not have less than 5 ppm dissolved salts, water having conductivity of about 0.25 micromho-cm is being used in the production of some high resistivity dielectric papers.

Ceramic Products

Water containing less than 5 ppm dissolved salts is used for washing some ceramic products before firing. Greater amounts of dissolved salts may sometimes leave marks or rings on the surface of the work after firing. In porcelain enamel plants,[18,19]

TABLE 2
Partial List of Industries and Processes Using High Purity Deionized Water

Air Conditioning
Beverage preparation
Catalyst manufacture
Ceramics processing
Chemicals production
Cosmetics manufacture
Diesel power plants
Distilleries
Elastomers production
Electrochemical processes
Electronics production
Electroplating operations
Explosives manufacture
Elixir compounding
Food processing
Gelatine manufacture
Glass manufacture
Ice manufacture
Latex paint production
Leather manufacture
Mirror silvering
Paper manufacture
Pharmaceutical manufacture
Photography
Plastics manufacture
Power plants
Printing
Radio broadcasting stations
Railways
Research laboratories
Storage batteries
Television tube manufacture
Textile processing

water containing excessive dissolved solids has a serious effect on the workability of the enamel as it is used as a mill addition, imparting temporary set to the enamel and causing it to be erratic in set while being applied. The use of distilled or deionized water overcomes this problem.

Synthetic Textile Fibers

High purity water is required in rinsing and processing of some synthetic textile fibers. One deionization plant in this service can furnish water with as low a conductivity as 0.07 micromho-cm; it cuts off at about 1 micromho-cm. In a rayon manufacturing plant, water containing 4 ppm dissolved solids is used.[20] In a synthetic plastics plant water containing 5 ppm dissolved solids is used.[20] Manufacturers of latex paints are beginning to use high purity water in making emulsions, in some cases using water with a conductivity as low as 1 micromho-cm conductivity. The presence of small amounts of metallic salts in process water is said to affect the stability of emulsions.

Electroplating Plants

In electroplating plants, high purity water is used for making up plating baths and for final rinsing of the product after plating.[12] Chlorides are harmful in zinc cyanide plating baths. Chlorides, sulfates, and carbonates are harmful in silver plating and deionized, decarbonized water is used. In anodizing aluminum, high purity water is preferred. This is because chlorides and sulfates otherwise may be built up, by evaporation, beyond the allowable limits.

Water comparable to distilled water in quality is required in the silvering of mirrors. It is particularly necessary to maintain a chloride content of less than 1 ppm. The process water is used for the ammoniacal silver nitrate plating solution as well as for mirror rinsing.[15]

In the production of electrolytic tin plate, deionized water containing about 5 ppm dissolved salts is used in rinsing operations to prevent streaks, strains and surface irregularities.[21] Because the water must travel through steel piping for about two miles in one plant a vacuum deaerator also is installed. Here this water also has replaced triple-distilled water in the cooling systems of three high-frequency induction heating units whose output totals 3,000 kilowatts of radio frequency power—the equivalent of 60 modern radio stations.

Ice Plants

Some ice plants use water with 1 to 2 ppm dissolved salts and low silica together with deaeration to eliminate "mush" spots at the top ends of ice cakes. Dissolved salts in the water tend to concentrate at the top as the cake freezes leaving these mushy spots which must be sawed off at some expense.

Distilleries use high purity water for "cutting" the alcohol in blending.[16] Some dieselized railroads[22] use water having approximately 5 ppm dissolved salts for diesel cooling systems and for feed to compact train-heating boilers where water is flashed immediately to steam. Water with about 5 ppm dissolved salts is used for washing aluminum silicate bead catalyst during their manufacture.[20]

Materials of Construction

High purity water has been referred to as "hungry water." Having been robbed of most of its ions it apparently is very anxious to acquire more and come to some more peaceful equilibrium condition. If deaerated, it has a strong affinity for oxygen and carbon dioxide if exposed to the air. In most of the applications cited in this paper the water probably is handled at temperatures below 200 F, except in the case of boilers and feed water heaters. Nevertheless considerable pains are taken to avoid opportunity for the pickup of metallic ions.

In many installations the pure water leaving the ion exchange equipment is handled in piping, valves and pumps of rubber-lined construction.[23] In some cases Saran-lined piping and fittings are used.[8] Wilkes[22] described a deionizing installation where rubber-lined pipe was used in sizes above 2½ inch diameter and solid Uscolite pipe for smaller sizes.

Harlow, Calise and Lane[24] described a power plant installation where the 12 inch diameter deionized water effluent piping to the storage tank and the storage tank itself are lined with a multi-coat sprayed-on polyvinyl chloride coating. This coating also is used in the pipe line carrying the water to the boiler feed water heaters.

In another plant transite pipe with vinyl chloride coating has been in satisfactory service four years.[22] Sheet linings of polyvinyl chloride resins appear to be inert and highly resistant. These are affixed with special cements and flash welded at the joints. In one case after two years service there appeared to be some deterioration of the cement bond.[25]

Austenitic Stainless Steels

The austenitic stainless steels apparently have given satisfactory performance in handling high purity water. Television tube manufacturers and distillers have used both Types 304 and 316 stainless for complete systems handling deionized water, including piping, valves and storage tanks. In one plant[25] storage tank linings of 18 gauge 304 stainless gave better performance than several types of synthetic resin coatings tried. In another case[22] stainless steel solenoid valves were used in a deionized water effluent line where brass valves corroded. Monel and Inconel have been used satisfactorily for storage tank linings. In one plant[25] Monel-clad steel tanks were used to replace glass-lined tanks which contaminated the water with silica and rubber-lined tanks which failed in service.

Churchill and Brown[26] reported that a survey of 14 distilled water systems using aluminum tanks and tubing showed good performance for the aluminum equipment in all cases with zero to insignificant amounts of aluminum pick-up in the water. In this service aluminum tanks should be conditioned before use by several fillings with tap water followed by a filling with the high purity water and draining.

Aluminum-Sprayed Storage Tanks

Examination was reported[25] of two closed aluminum-sprayed 34,500 gallon storage tanks after six years service handling condensate water containing 2 ppm total dissolved solids, including less than 0.01 ppm silica. The conductivity was 2.5 micromho-cm and the pH 8.6; the condensate water was stored at 140-180 F. The sprayed coating was in good condition at overlaps but the tank rusted badly in other areas with pits as much as 50 mils deep, caused apparently by porosity in the coating. In water of this high resistivity the aluminum apparently does not protect the exposed steel galvanically as it might with a better electrolyte.

In a power plant installation[8] deaerated deionized water to which some caustic potash was added to give pH 7-7.5, was transported a distance of 1.1 miles to one of the boiler plants. It was transmitted through cast iron pipe lined with bitumastic with a section of about 1000 feet of steel pipe where the line passed over a bridge and overpass. Iron pickup by the water in passing through this line was less than 0.05 ppm.

In a tin-plating plant,[21] deionized water containing 5-10 ppm dissolved salts was deaerated and then piped about two miles through bare steel pipe.

Steel Storage Tanks

Examination was reported[25] of the interior of two 50,000 gallon closed bare steel storage tanks after three years' service handling deionized water. This water contained approximately 2 ppm total dissolved solids including 0.1 ppm silica and had a conductivity of about 5.5 micromho-cm, with a pH of 8.1-8.4. The water was stored at 140-160 F. Inside the tank there were heavy red rust deposits and scale as much as ¼ inch thick, with randomly scattered mounds of mushy brown rust which easily sloughed off the surface with shallow pits underneath.

At another plant[25] examination was made after three years service of three 20,000 gallon closed bare steel storage tanks. These tanks had handled condensate water containing 0.4 ppm total dissolved solids including 0.10 ppm silica with conductivity of 3 micromho-cm. The condensate water had been handled at 140-180 F. The tank interiors were heavily incrusted with tan rust formations of uniform density and relatively smooth surfaces as much as ½ inch thick, with pitting attack underneath. In both of these cases there was opportunity for oxygen and carbon dioxide to be absorbed by the water.

In contrast, examination of a 64,000 gallon closed bare steel storage tank after six years service showed it to be in relatively good condition with some pitting and uniform scale type of attack at the water line. The tank had handled evaporated distillate, Zeolite softened, with total dissolved solids of 69 ppm including silica content of 2 ppm, and conductivity of 138 micromho-cm. The pH was 7.0-8.0, and storage temperature was 80-130 F.

Partridge[27] has reported in detail several cases of stress corrosion cracking of steel subject to localized stresses in power plant boilers operating at pressures from 850 psi to 1400 psi and using deaerated distilled or deionized water for boiler feed. In these cases the pH of the water in contact with the steel ran from 7.0 to 9.5. The occurrence of stress cracking is attributed to the inability of the steel to form a protective film of oxide in water with pH values this low. Performance of steel apparently is much better when the boiler water is chemically treated to have a pH of 10.5 or above.

There seems no doubt that the industrial uses for high purity water will continue to increase and that a number of the applications will be at water temperatures up to 600 F and perhaps higher. At these higher temperatures little corrosion and wear data were available prior to the recent investigations, part of which are reported in the papers by Roebuck[1] and DePaul.[2] The availability of this information for design and operating purposes should stimulate thinking on the part of plant engineers as to new ways to use high purity water for the improvement of plant operations in numerous industries.

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PREVENTIVE MEASURES, CA

Partial protection is also very desirable in many cases involving poorly coated lines and can be justified by reductions in sinking fund deposit factors due to increased pipe life, in addition to usual savings in operations.

Electrical engineers should anticipate that cathodic protection will effect savings in other corrosion areas. Power plant equipment, cables, substations, docks, ships and other situations involving metals in contact with soils and solutions are fertile fields for the application of cathodic protection and modern techniques of corrosion control

5.2.1-56 CORROSION CONTROL OF STEEL EQUIPMENT. T. R. B. Watson. **Can. Chem. Processing**, 37, No. 10, 46, 48, 50, 52, 54 (1953) Sept.

Describes causes of corrosion and discusses control by means of cathodic protection.

5.2.1-57 CATHODIC PROTECTION LICKS CORROSION. L. C. Werkin. **Petroleum Refiner**, 31, No. 9, 122-124 (1952) Oct.

Cathodic protection, a positive, controllable and inexpensive method of preventing corrosion. There is real money in reducing these losses caused by corrosion-maintenance, replacement costs, over-design of equipment, and product losses. Refinery management and technical personnel must be keenly aware of the creeping inroads of corrosion, and alert to any feasible solution to the problem. Table showing cost estimates and savings resulting from its use on a large open-box-type refinery condenser and a large diameter Dorr clarifier. 9 refs.

...THODIC PROTECTION OF STEEL. F. ...Nurse, H. C. K. Ison and T. W. Farrer. ...try, No. 40, 972-974 (1952) Oct. 4.

...rrent and potential requirements for ...teel in sea water and in the presence ... Protection of mild steel in sea ...ly stages at a relatively noble ...nsity is sufficiently high, ...gh a steel anode. If a ... protection can be ...a small current ...esence of the

...1.6–3, 4; 4.5.1–1; 4.5.3-6.3.8–6; 7.2–17, 44; 8.4.2–8; 8.4.3-8.9.5–12

5.2.2 PREVENTIVE ... PROTECTION, AN...

a. General ...

b. Magnesium ...

5.2.2-1 CATHODIC PRO... ANODES. Brochure, June, 1953 ... tute, 60 East 42nd Street, New ...

Merits of zinc anodes (con... and with rectified systems) in... ing distribution piping, tra... condensers. Practical ...

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T-7 Takes Over Work of Correlating Committee

Regional Groups to Extend Cathodic Protection Function

Work of the Correlating Committee on Cathodic Protection was summed up in the final Report of the Correlating Committee on Cathodic Protection published in July 1951. The committee was formed in 1946 to prepare and disseminate information about cathodic protection and encourage its beneficial use. Ten national industrial organizations and an engineering association cooperated in sponsoring the committee. Sponsor organizations were American Gas Association, American Petroleum Institute, American Public Works Association, American Water Works Association, Association of American Railroads, Bell System, Edison Electric Institute, International Municipal Signal Association, Inc., National Association of Corrosion Engineers, United States Independent Telephone Co. and Western Union Telegraph.

H. H. Anderson, chairman of the committee, was responsible largely for formation and success of the activity. Mr. Anderson represented the American Petroleum Institute on the committee and was employed by the Shell Pipe Line Company at the time.

The Correlating Commitee was placed in an inactive status after the final report was published in 1951.

In recent years expansion of underground plant and facilities has increased the need for correlation of cathodic protection and cooperative work has increased. Many new electrolysis and coordiuating committees have been formed and older existing committees have had increased activity, creating a need for a national group to provide liaison among local area committees and a central organization in channeling information on cooperative work to all concerned.

Rather than ask the Correlating Committee to reactivate, it was decided it would be more logical and workable to form a committee under one organization concerned with corrosion. NACE agreed to sponsor such a group and authorized formation of a new Technical Group Committee T-7 called Corrosion Coordinating Committee. The organization of T-7 is listed in the Directory of NACE Technical Committee in this issue of CORROSION. Group Committee T-7 is the national committee composed of a chairman, vice-chairman and chairmen of the six regional unit committees. The regional unit committees have the same geographical boundaries as the six regions of NACE. Area electrolysis and coordinating committees will be affiliated as area subcommittees under the appropriate regional unit committee.

Of major benefit to persons connected with cathodic protection of underground plant will be a complete listing of officers of all committees and sub-committees in every other issue of CORROSION. For example, a corrosion engineer of a gas transmission line, communication, or power company, desiring information on installations in a given area would contact the chairman of the area sub-committee. The chairman will have an up-to-date listing of the persons in companies participating in committee activities in the area who are responsible for joint testing, etc. Some committees, such as T-7D-1 Houston Area Corrosion Coordinating Committee will have maps showing installations in the area.

Projects to be undertaken by T-7 include preparation of suggested standard notification forms and suggested standard by-laws for area coordinating committees. One of the first aims of the committee is to revise the final report of the Correlating Committee on Cathodic Protection to include recommendations of the T-7 committees and to publish revision for wide distribution.

Latest officers chosen to head up regional unit committees of T-7 include: T-7B North Central Region, J. O. Mandley, Michigan Consolidated Gas Company, Detroit, vice-chairman; T-7D South Central Region, O. W. Wade, Transcontinental Gas Pipe Line Corporation, Houston, chairman and C. L. Woody, United Gas Corporation, Houston, vice-chairman; T-7D-1, Houston Corrosion Coordinating Committee, C. L. Mercer, Southwestern Bell Telephone Company, Houston chairman; T-7F Canadian Region, C. L. Roach, The Bell Telephone Company of Canada, Montreal, Quebec, chairman and R. E. Kuster, Union Gas Company of Canada, Ltd., Chatham, Ontario, vice-chairman.

T-7 meetings have been held at Philadelphia, San Antonio, Texas and Detroit. These were held primarily to organize the regional unit committees.

An important T-7 meeting will be held in St. Louis in connection with the Thirteenth Annual NACE Conference, March 11-15 of this year.

Polyeurethane, Hypalon Committees Are Organized

Task Groups have been formed under Unit Committee T-6A on Polyurethanes and Hypalon coatings for resistance to chemical corrosion. Task Group T-6A-17 on Polyurethanes will be under the chairmanship of Otto H. Fenner, Monsanto Chemical Company, St. Louis and Task Group T-6A-18 on Hypalon will be under the chairmanship of J. R. Galloway, E. I. du Pont de Nemours & Company, Inc., Houston.

Other coatings and linings assigned to T-6A task groups include heavy linings, vinyl coatings, vinylidene chloride polymers, phenolics, polyethylene, rubber and elastomers, silicones, methyacrylates, furanes, polyesters, fluorocarbons, chlorinated rubbers, organic-brick covered, rigid vinyls and bituminous coatings.

Technical Unit Commitee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion was organized for the purpose of assimilating and disseminating to corrosion engineers factual and quantitative data on the performance and limitations of the various organic bases successfully used as coatings and linings for corrosion mitigation. To date, four reports have been completed and published in CORROSION. These include application techniques, physical characteristics and chemical resistance of 1) Polyvinyl Chlor-Acetates, 2) Epoxy Resins, 3) Rigid Polyvinyl Chlorides, and 4) Chlorinated Rubber coatings. Reports on other types of coatings and linings are being prepared and will be published when completed.

Officers of the committee are: R. McFarland, Hills-McCanna Company, Chicago, Ill., chairman; C. G. Munger, Amercoat Corporation, Southgate, Cal., vice-chairman and J. I. Richardson, Amercoat Corporation, Southgate, secretary. The thirty eight members represent users, applicators and raw materials manufacturers.

Robinson Heads Offshore Installations Subcommittee

R. M. Robinson, Continental Oil Company, New Orleans, Louisiana, and O. L. Grosz, The California Company, Harvey, Louisiana, have been elected chairman and vice-chairman respectively of Technical Unit Committee T-1M on Corrosion of Oil and Gas Well Producing Equipment in Offshore Installations. Outgoing officers are D. F. Dial, Jr., Pure Oil Company, Houston, chairman and F. E. Blount, Magnolia Petroleum Company, Dallas, Texas, vice-chairman.

Dial and Blount were the first officers of T-1M and have played a major role in the successful formation and organization of the commitee activities. Under their leadership the committee has sponsored a short course on coating application, a symposium on marine corrosion, several individual papers on marine corrosion and has completed proposed specifications for application of coatings in marine environments.

Next meeting of the commitee will be held in St. Louis in connection with the Thirteenth Annual NACE Conference next March.

Maintenance Painting Unit Elects Permanent Officers

J. C. Coffin, The Dow Chemical Company, Midland, Michigan and R. S. Freeman, Cities Service Refining Corporation, Lake Charles, Louisiana have

(Continued on Page 104)

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Maintenance Painting—

(Continued from Page 103)

been elected chairman and vice-chairman respectively of Unit Committee T-6D on Industrial Maintenance Painting. Coffin and Freeman had been serving as temporary officers during the organization of the committee and were officially elected to office by letter ballot to committee members.

T-6D held an organization meeting in San Antonio, Texas during the 1956 South Central Region Meeting. The committee was formed to discuss, study, report and submit for publication information relative to industrial maintenance painting and to advance the cause of corrosion engineering by informing process industries and their supervisory personnel of the advantages to be gained by sound corrosion control and prevention practices. Emphasis will be placed on protective coating application and painting programs.

Areas in which committee work will be done include, economics, standardization of scope for painting specifications and painting programs, including records, inspection and similar field problems. Task Groups assigned and their officers are: T-6D-1 on Economics, S. L. Lopato, Carboline Company, St. Louis, chairman; T-6D-2 on Specifications, L. L. Sline, Sline Industrial Painters, Inc., Houston, chairman and, T-6D-3 on Painting Programs, R. H. Bacon, The Dow Chemical Company, Inc., Freeport, Texas.

The next meeting of the committee will be held in St. Louis next March.

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Certificates of membership in the National Association of Corrosion Engineers will be issued on request at $2 each, remittance in advance. The certificates, which measure 5½ x 8½ inches, are signed by the president and executive secretary of the association.

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Soil Box Demonstration Scheduled for Pipeliners

St. Louis Program to Feature "Transparent Meter" Presentation

Electrical currents generated by metals corroding underground will be measured in a soil box demonstration to be given as a feature of the Pipe Line Group Discussion program at St. Louis. The discussions, to be held on the afternoon of March 12 during the NACE 13th Annual Conference at St. Louis, will feature the transparent meter, readings from which are projected on a screen for the audience. M. C. Miller and A. W. Peabody, engineers with Ebasco Services, Inc., New York, will conduct the demonstration.

Discussion leaders will demonstrate the fundamentals of soil and galvanic corrosion of buried metals and cathodic protection. They use a large box of corrosive soil in which are buried pieces of pipe, cable, wire and other metals commonly used in pipe lines, cable systems and metallic structures. Galvanic potentials developed by these materials will be measured and their significance in corrosion control will be shown. Various methods of making potential surveys and the results achieved by each will be demonstrated.

Cathodic Protection Application

Application of cathodic protection through the use of galvanic anodes and rectifiers will be demonstrated so that the audience can see how the corrosion current is affected by the control efforts and when protection is achieved. Various methods of determining when protection is achieved will be demonstrated and discussed. Potential readings of metals taken to "close" and "remote" reference electrodes will be made and the corresponding potential readings projected and their meaning discussed.

Use of Device Explained

The demonstrators will show how the soil box and its related specimens and instruments can be used as a convincing educational tool for persons interested in underground corrosion control.

Mention will be made of a new "student" low cost meter made available to students who wish to learn the principles of cathodic protection through the use of a "kitty box."

Messrs. Miller and Peabody believe this is the kind of demonstration which permits management concerned with the cost of corrosion to learn what corrosion actually is and how cathodic protection works. Engineers will find the demonstration interesting and can expect to gain ideas on how to improve their methods of instruction for new corrosion workers. The young corrosion engineer will find the demonstration invaluable, they believe.

Consequently, a special invitation to management and junior engineers is extended. Ample opportunity will be offered during the two and one-half hour session to ask questions.

C. L. Woody, United Gas Corp., Houston, is chairman of the pipe line discussion program.

More Papers Prepared for NACE St. Louis Program

Technical papers being prepared for the 13th Annual Conference of the National Association of Corrosion Engineers at St. Louis March 11-15 include:

Control of External Corrosion of the Trans-Arabian Pipeline, F. M. Maasry.

Application of Cable in Cathodic Protection, R. G. Fisher, The Okonite Co., Passaic, N. J. and M. A. Riordan, The Rio Engineering Co., Houston.

A report on the St. Louis technical program was published in December, 1956 CORROSION beginning on Page 112.

San Diego Section Hears Radiant Heating Corrosion Problems Discussed

Problems encountered in the installation and operation of radiant heating systems were covered in a talk by William T. Lieber, chief engineer of the University Heating and Air Conditioning Co. before a dinner meeting of 25 members and 21 guests of San Diego Section. The meeting was held November 28 at Lawton's Cafe, La Mesa, Cal.

Ambrose R. Nichols, Jr., of San Diego State College also presented but did not attempt to answer some of the questions on fundamental problems of corrosion control. He touched briefly on formation of hydrogen films, solution potentials, overvoltages and high temperature corrosion, showing where theoretical concepts have no answers for actions taking place and the difficulty of obtaining answers. Mr. Lieber said radiant heating systems are becoming more popular.

Less Than 25 Booths Unsold for Exhibition

Less than 25 booths remained unsold at the 13th Annual Exhibition of the National Association of Corrosion Engineers at Kiel Auditorium, St. Louis, March 12-15. Remainder of the booths have been assigned to 91 exhibitors whose names are listed below:

Alloy Steel Products Co.
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(Continued on Page 106)

NOTICE ON PAYMENT OF 1957 NACE DUES

Invoices for 1957 membership dues have been sent to all Acitve and Junior NACE members. These dues are payable January 1, 1957. The NACE by-laws state that no member with dues in arrears for three months shall receive the publications of the association until such dues are paid.

• Accordingly the names of Active and Junior members whose 1957 dues have not been received by March 30, 1957 will be removed from the mailing list to receive CORROSION. No mailings of CORROSION will be made to delinquent members until dues are paid.





LADIES' PROGRAM at St. Louis Conference includes visits to (left) Jewel Box botanical exhibit; (right) St. Louis Art Museum.

Week's Program of Entertainment and Tours Outlined for Women Attending Conference

A full week of entertainment and tours has been scheduled for ladies accompanying their husbands to the NACE 13th Annual Conference and Exhibition at St. Louis March 11-15. Mrs. Mary Ellen Young, Ladies' Program Committee chairman outlined the following events:

Sunday, March 10—For early arrivals. Tea and coffee will be served informally beginning at 2:30 pm at the ladies' headquarters room, Sheraton-Jefferson Hotel.

Monday, March 11—Get acquainted coffee hour between 9 and 10 am, Ladies Headquarters Room.

"Fashions in Flowers," special instruction in flower arrangements. Each lady will be assisted in making her own corsage.

Tuesday, March 12—St. Louis Day. Following the 9 am coffee hour, the group will be introduced to the host city in a "Meet St. Louis Program."

A tour of St. Louis points of interest will be available, including a stop at the Jewel Box, a botanical exhibit at the Jefferson Memorial. Lindbergh trophies are displayed there also.

A buffet luncheon will be served at 1 pm in the Sculpture Room of the St. Louis Art Museum.

From 6 to 7 pm ladies are invited to attend the annual Fellowship Hour in the Gold Room of the Sheraton-Jefferson Hotel.

Wednesday, March 13—St. Louis hostesses will have their cars ready for shopping tours to the fashionable suburbs or antique sections.

Thursday, March 14—A box lunch get-together on the show boat Golden Rod in the Mississippi River will be followed by a melodrama.

(The annual banquet will be held Wednesday. While this event is not included in the ladies program, many will elect to attend it.)

The Ladies Headquarters Room will be open daily for card playing.

All activities and transportation are included in the ladies' registration fee.

Many Questions Asked After Nee's Talk on Polyamids

Many questions and considerable discussion followed the presentation of John W. Nee's talk on Polyamid Resins —A New Surface Coating Material before Central Oklahoma Section. Mr. Nee is with Briner Paint Mfg. Co., Corpus Christi. The 21 members and guests present November 27 attended a dinner meeting at Tropical Cafeteria, Oklahoma City.

E. G. Stevens, Dowell, Inc. was elected section chairman. Other officers elected were R. V. James, University of Oklahoma, vice-chairman and Dan H. Carpenter, Aquaness Dept., Atlas Powder Co., trustee.

The January 22 meeting of the section is scheduled to hear Frank Burns, Kerr-McGee Industries discuss pipe line coatings.

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Baton Rouge, La.

Electrochemical Society And Cleveland Section to Meet Jointly January 9

A joint meeting with The Electrochemical Society is scheduled for January 8 by Cleveland Section. The meeting will have as technical speaker Dr. R. Ladd, National Advisory Committee for Aeronautics.

The December 18 meeting of Cleveland Section programmed M. G. Fontana, Ohio State University, who talked on corrosion.

Other meetings listed by the section are:

Feb. 19—Atomic Power for Industry by a speaker from Cleveland Electric Illuminating Co.

March 19—Copper and Its Alloys, Including Aluminum Bronze for Use in Corrosive Environments, I. S. Levinson, Ampco Metals, Inc.

April 16—Atmospheric Corrosion, R. B. Hoxeng, Applied Research Laboratories, U. S. Steel Corp.

May 21—Epoxy Resin Coatings, Ralph Madison, director of research, Truscon Laboratories.

At the section's November meeting R. McFarland, Hills-McCanna Co., chairman of T-6A on Organic Coatings and Linings for Resistance to Corrosion talked on equipment linings for corrosive service. About 60 members and guests were present.

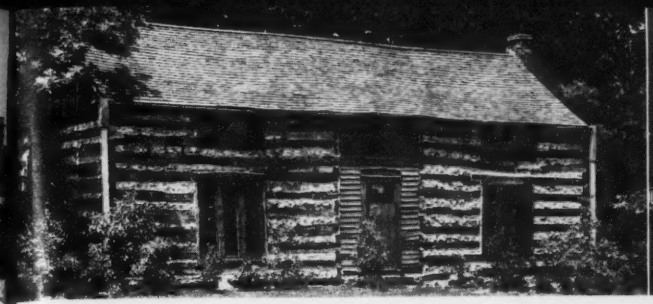
Less Than 25 Booths—

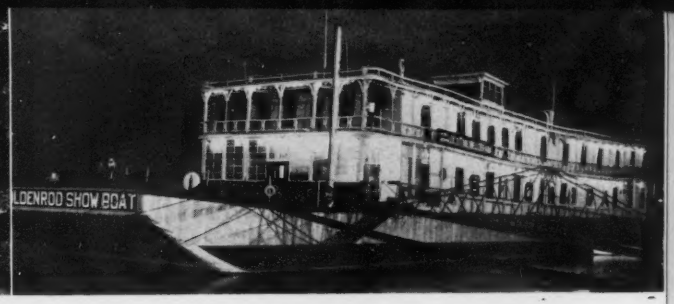
(Continued from Page 105)

Phelps-Dodge Copper Products Corp.
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Plastics Products, Inc.
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Remco Mfg. Co.
Rem-Cru Titanium Inc.
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Shell Oil Co.
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Tapecoat Company
Texsteam Corp.
Tinker & Rasor
Tretolite Co.
Truscon Laboratories
Union Carbide & Carbon Corp.
U. S. Stoneware Co.
Visco Products Co., Inc.
T. D. Williamson, Inc.

Coating Tubing Internally Is Topic at Corpus Christi

Joe Duesterberg of Plastic Applicators, Inc. presented a paper on Coating Tubing Internally at the November 27 meeting of the Corpus Christi Section attended by approximately 38 members and guests. Following Mr. Duesterberg's presentation, new officers for 1957 were elected as follows: Hugh Wilbanks, Cathodic Protection Service, chairman; Kenneth Ray Sims, Gas Division, Department of Public Utilities, vice-chairman; and William Taylor, Gas Department, City of Corpus Christi, secretary-treasurer.





HISTORICAL Ulysees S. Grant log cabin is one of the spots on a tour of St. Louis planned for ladies attending 13th Annual NACE Conference. Right is a view of the river show boat where an old time melodrama will be enjoyed.

Chicago Section Hears Haase Discuss Coatings

"Protective Coatings—Their Behavior and Why," a talk by Harold F. Haase, corrosion consultant of Milwaukee featured the November 20 meeting of Chicago Section at Chicago Engineer's Club. There were present 74 members and guests.

Dr. Haase advocated protective coatings supplemented by cathodic protection, especially for metals submerged in water. He also recommended that laboratory test panels include sharp edges.

The Fellowship Hour was sponsored by Enterprise Paint Co., R. C. Lawson senior host assisted by A. F. Bohnert and J. D. Oppenlander. H. C. Boone, People's Gas Light and Coke Co., section secretary acted as master of ceremonies.

●

A chronological list of all articles published in CORROSION's Technical Section 1945-54 may be found in the 10-Year Index to CORROSION.

World Metallurgical Congress Is Scheduled

The Second World Metallurgical Conference will be held in Chicago November 2-8, 1957. The meeting is sponsored by the American Society for Metals.

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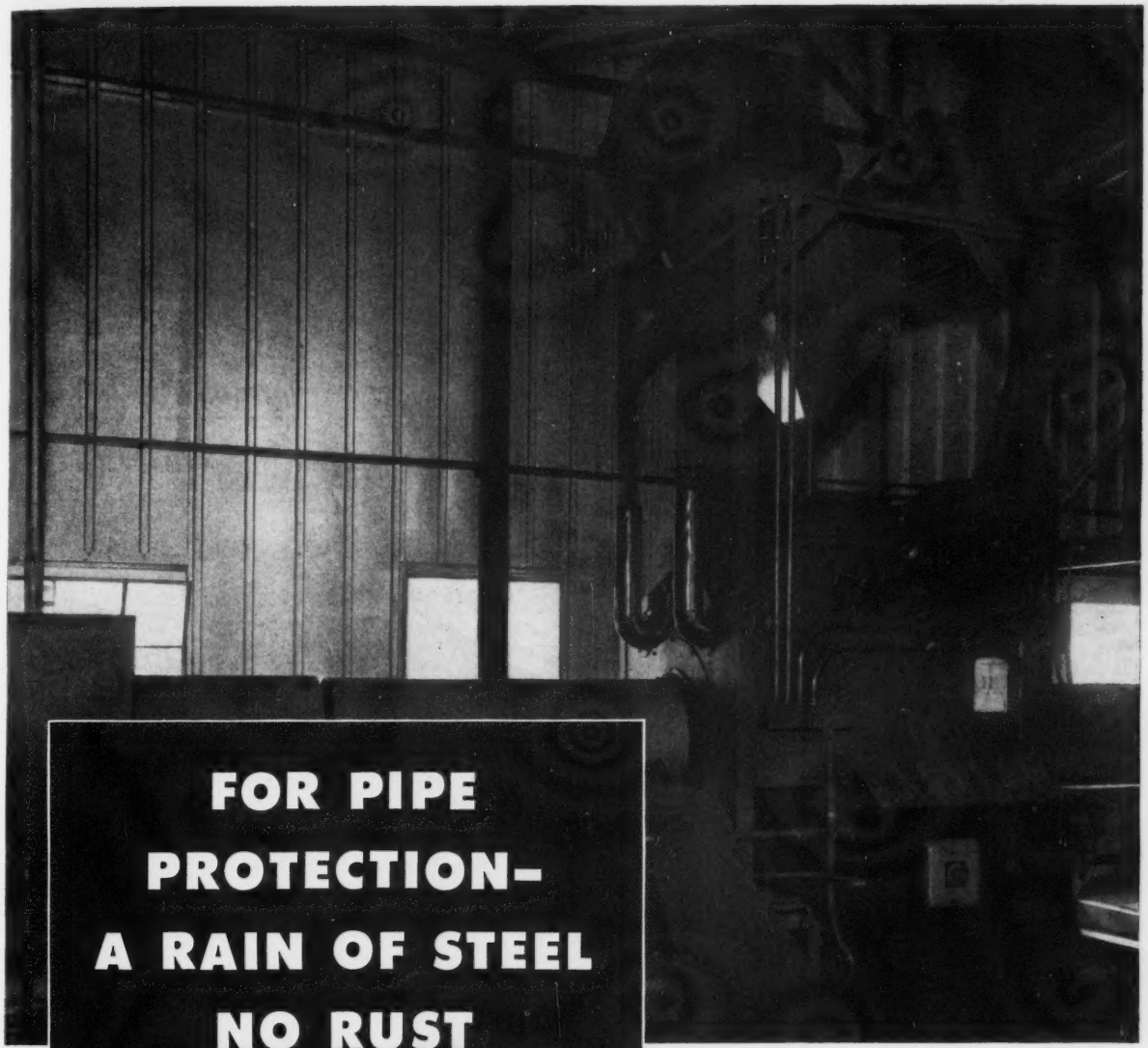
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HILARITY WAS UNANIMOUS at the December 12 ladies' night meeting of Houston Section featuring "Corrosion Engineer, This Is Your Life," a humorous skit on contrasting types of corrosion engineers. In the skit, left to right, top: C. C. Nathan, Texas Company, as the "big shot" engineer; second, as the "little shot" engineer with R. P. Suman, Pittsburgh Plate Glass Co. as the "wheeling and dealing" paint salesman; third, J. E. Rench, Napko Paint and Varnish Works, producer of the skit, is puzzled about what's going on; second row, first, Suman exemplies the "low pressure" paint salesman; second, Mrs. Maureen Carpenter, typifies the less desirable kind of secretary; third, Bob Lingle, Syd E. Culbertson Co., Inc. is the apologetic "boss"; lower, left, two pieces of the "three-piece symphony orchestra," O. A. Melvin, Carboline Co. and O. W. Wade, Transcontinental Gas Pipe Line Co., not pictured is Mrs. Wade, who accompanied on the piano; right, C. L. Mercer, Southwestern Bell Telephone Co., reading a scroll on which the "big shot" engineer is eulogized by the workers under him.



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North Texas Section Gives Revised Program Schedule

A revised program of meetings for North Texas Section has been issued as a substitute for one published on Page 94, October, 1955 CORROSION. Ed. Muelhause, Lone Star Gas Co., Dallas, section chairman, said so many changes were necessary a new program schedule was prepared.

Meetings are planned as follows:

Dec. 3—Cooling Water Corrosion by W. G. Ashbaugh, Carbide and Carbon Chemical Co. At Dallas.

Jan. 7—Relation Between Management and Corrosion Engineers, R. A. Brannon, Humble Pipe Line Co., Houston. At Fort Worth.

Feb. 4—Water Supply and Corrosion Problems, Henry Graeser, City of Dallas Water Dept. At Dallas.

March 4—Design for Corrosion, F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis. At Dallas.

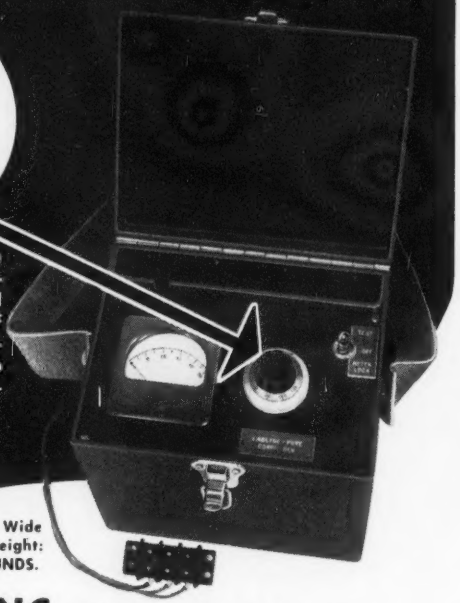
April 1—How to Evaluate Corrosion Inhibitors, Jay Simmons, Sun Oil Co., Dallas. At Fort Worth.

A meeting to be held in May will be the annual section picnic.

John Pool, Magnolia Pipe Line Co. and Ralph Petty, Sinclair Pipe Line Co. spoke to 18 members and 12 guests at the November 5 meeting in Dallas. Their topic was "Controlling Pipeline Corrosion by Using Cathodic Protection."

Mr. Pool gave a clear presentation of his company's method in using rectifiers, indicating that current requirement tests and soil resistivity surveys sometimes preceded the installation of a cathodic protection system. Mr. Petty's contribution pertained to magnesium anodes to protect pipe lines and petroleum industry containers.

Officers of the section, elected by secret ballot, were announced as follows: Howard Greenwell, Production Profits, Inc., Dallas, chairman; Glyn Beesley, Dallas Power and Light Co., vice-chairman; Ralph Petty, Sinclair Pipe Line Co., Fort Worth, secretary-treasurer and Paul Fleming, Gulf Oil Co., Fort Worth, trustee.

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Oil and Gas Journal 54 No. 29, 135 (1955)
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NACE MEETINGS CALENDAR

Jan.

3 Pittsburgh Section. Mid-East Pipe Line, L. P. Sudrabin, Electro Rust-Proofing Corp. at Mellon Institute.

7 North Texas Section. Relation Between Management and Corrosion Engineer, R. A. Brannon, Humble Pipe Line Co., Houston.

9 Central Oklahoma Section.

10 Niagara Section. Stress Corrosion. Business meeting.

15 Chicago Section. J. R. Spraul, General American Transportation Company, East Chicago, Ind., Corrosion Problems in Transportation Vehicles.

17 Kanawha Valley Section. John J. Halbig, Research Laboratories, Armco Steel Corp., Middletown, Ohio.

21 Lehigh Valley Section. A discussion of paint by Francis Scofield. Keystone Trail Inn, Allentown, Pa.

24 Sabine-Neches Section. Metallurgist's Approach to Corrosion. Little Mexico Restaurant, Orange, Texas.

24 Detroit Section. A. J. Thompson, Allis-Chalmers Mfg. Co., Milwaukee, Cavitation and Impingement Attack in Pumps. Dinner meeting.

Feb.

4 North Texas Section. Water Supply and Corrosion Problems, Henry Graeser, City of Dallas Water Dept.

5 Philadelphia Section. Kel-F for Corrosion Control, Francis J. Honn, M. W. Kellogg Co.

6 New England Section. Corrosion by Portable Waters, Samuel Jacobson, New Haven Water Co.

7 Pittsburgh Section. National president's and past section chairmen's night. Gateway Center.

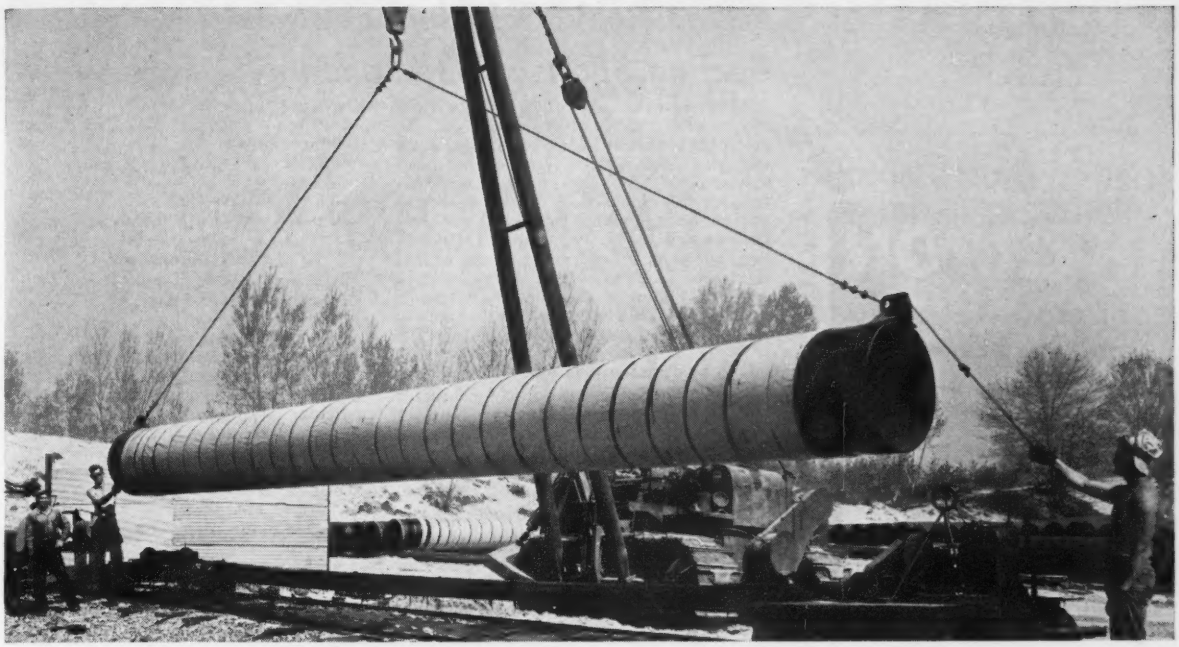
19 Chicago Section. Nickel Alloys and Their Uses, T. F. Drantz, Haynes Stellite Co.

19 Cleveland Section. Atomic Power for Industry.

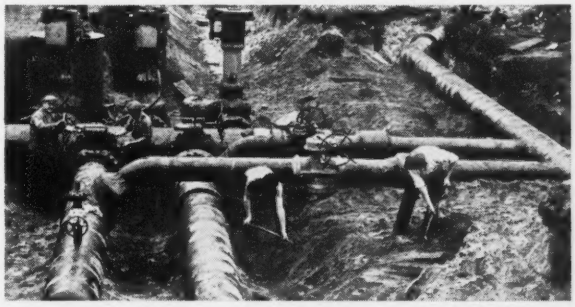
20 Greater Boston Section. Design Against Corrosion, F. L. LaQue, The International Nickel Co., Inc.

21 Detroit Section. Joint meeting with The Electrochemical Society. Milton Stern, Electro Metallurgical Corp., Niagara Falls: Fundamentals of Electrode Processes in Corrosion.

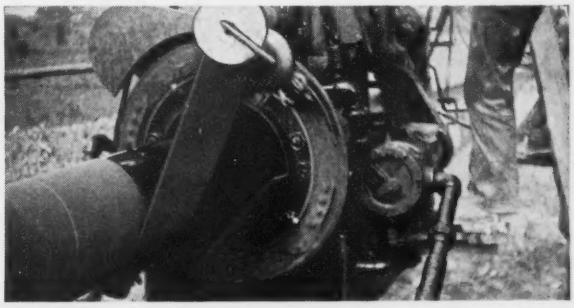
28 Sabine-Neches Section. Corrosion Problems in the Chemical Industry, Little Mexico Restaurant, Orange, Texas.



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Round Robin Schedule Outlined for Houston Section Short Course January 31-February 1

A round-robin schedule for the two-day short course on corrosion to be given by Houston Section in cooperation with the University of Houston has been announced. The course will be held January 31-February 1. Advance registration accompanied by a $10 fee will be accepted by O. W. Wade, Transcontinental Gas Pipe Line Co., Box 296, Houston 5, Texas. The fee covers a printed version of the course content.

The schedule announced for the course follows:

Thursday, January 31

7:45-8:15 am—Registration, Oberholtzer Hall, University of Houston, Wheeler and Cullen streets.
8:15-9:45 am—All registrants, Fundamentals of Corrosion, Marshall Parker, Cormit Engineering Co., Houston.
Coffee break
10:15-11:45 am—The registrants will be organized into five groups who will be divided among the following classes:
Pipe Line Corrosion and Fundamentals of Cathodic Protection, M. A. Riordan, Rio Engineering Co., Houston.
External Coatings of Pipe Line Structures for Underground Service, E. R. Allen, Jr., Galveston, Texas.
Internal Corrosion of Pipe Lines and Methods of Control, R. A. Brannon, Humble Pipe Line Co., Houston (Tentative).
Protective Coatings for Tanks and Above Ground Structures, L. G. Sharpe, Napko Co., Odessa, Texas and E. W. Oakes, Clemtex, Inc., Houston.
Design, Construction and Maintenance Planning for the Prevention of Corrosion on Pipe Lines, Pierce R. Butterfield, Transcontinental Gas Pipe Line Corp., Houston.
11:45 am-1 pm—Lunch
1-2:30 pm—Second round robin period.
30 minute coffee break
3-4:40 pm—Third round robin period.
10 minute break
4:40-6:10 pm—Fourth round robin period.
6:10 to 7:30 pm—Dinner.
7:30 pm-9 pm—Fifth round robin period.

Friday, February 1

8-8:15 am—Instructions to each group by group leader. (A sixth class, on cathodic protection by Marshall Parker, will be added to the five held on Thursday. Classes will be devoted to the same subjects, stressing case histories, demonstrations and paying particular attention to instruments, and their functions. Discussions will be held at each class.)
8:15-9:20 am—First round robin class.
15 minute break
9:35-10:40 am—Second round robin class.
15 minute break
11:15-12 noon—Third round robin class.
12-1 pm—Lunch.
1-2:05 pm—Fourth round robin class.
15 minute break
2:20-3:40 pm—Fifth round robin class.
15 minute break
3:55-5 pm—Sixth round robin class.

Houston Section Holds Annual Student Night

University students from Texas A & M, Rice Institute, the University of Houston and Lamar Technological Institute made a brief acquaintance with corrosion engineers at the annual Student Night meeting held by Houston Section November 11 at John's Restaurant.

The group heard Walter H. Davidson speak on "Management's Interest in Corrosion." Mr. Davidson, an alumnus of Texas A & M is vice-president in charge of operations for Transcontinental Gas Pipe Line Co. A total of 85 members and guests attended. Student guests are sponsored each year by NACE members and attend without charge.

East Texas Section Elects New Officers for Year

The following officers have been elected for 1957 for East Texas Section: P. E. Happel, Sun Oil Company, chairman; Gene E. Smith, Lone Star Steel Company, vice-chairman; E. L. Chapin, Stanolind Oil and Gas Company, secretary; J. H. Graves, Tidal Pipe Line Company, treasurer, and J. C. Orchard, Cardinal Chemical Company, trustee.

Epoxy Resins Discussed At Detroit Section Meeting

Uses of Epoxy Resins for Corrosion Protection was the topic of Harry Howard, Shell Chemical Co., New York before 55 members and guests of Detroit Section October 25. Mr. Howard covered their nature, behavior and characteristics as protectives in thin and thick films.

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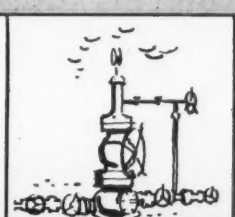
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CORROSION INHIBITOR NEWS

Philadelphia Section Hears LaQue on Materials Testing

F. L. LaQue of The International Nickel Co., Inc., is the scheduled technical speaker at the December 13 meeting of Philadelphia Section. The dinner meeting also featured the annual Christmas party of the section and a Fellowship Hour beginning at 5:30 pm.

Mr. LaQue, presently a vice-president of The International Nickel Co., Inc., New York is a past president of NACE, a recipient of the Speller Award and the Edgar Marburg Lecturer for ASTM in 1951. A founder of the Sea Horse Institute, he has been active in corrosion work since he joined Inco in 1927. He has specialized in properties and applications of corrosion resistant materials.

His discussion covered tests designed to facilitate choosing materials suitable for process equipment with special attention to designing and interpreting corrosion test results in the light of reactions such as pitting and crevice corrosion and the effects of heat treatment, stress, galvanic reactions, velocity and cooling.

European Corrosion Group To Meet May 31-June 8

The European Federation of Corrosion is planning to hold its Second Congress at Frankfurt am Main, 31 May-8 June 1958.

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NATIONAL, REGIONAL MEETINGS and SHORT COURSES

1957

Mar. 11-15—NACE Annual Conference. Kiel Auditorium, St. Louis, Missouri.

May 20-22—Northeast Region Corrosion Control Conference, Syracuse University, Syracuse, N. Y.

1957

Oct. 1-4—North Central Region, Chicago, Sherman Hotel. Exhibition.

Oct. 1-4—South Central Region, Oklahoma City, municipal auditorium. Exhibition.

Nov. 12-14—Northeast Region Fall meeting, Pittsburgh, Pa.. Penn-Sheraton Hotel.

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

1958

October 20-24—South Central Region. New Orleans, Roosevelt Hotel.

1959

NACE Annual Conference, Sherman Hotel. Chicago, Illinois.

SHORT COURSES

January 31-February 1—Houston Section. University of Houston.

April 2-4—University of Oklahoma, Norman and Central Oklahoma Section NACE.

February 13-15—Eighth Annual Tulsa Corrosion Short Course, February 13-15, Mayo Hotel, Tulsa.

Exhibitions Scheduled at October Regional Meetings

Exhibitions have been scheduled at meetings of South Central Region in Oklahoma City and of North Central Region in Chicago. The Oklahoma City meeting and exhibition will be held in the city auditorium while the Chicago meeting will be held at the Sherman Hotel. Both meetings will take place October 1-4.

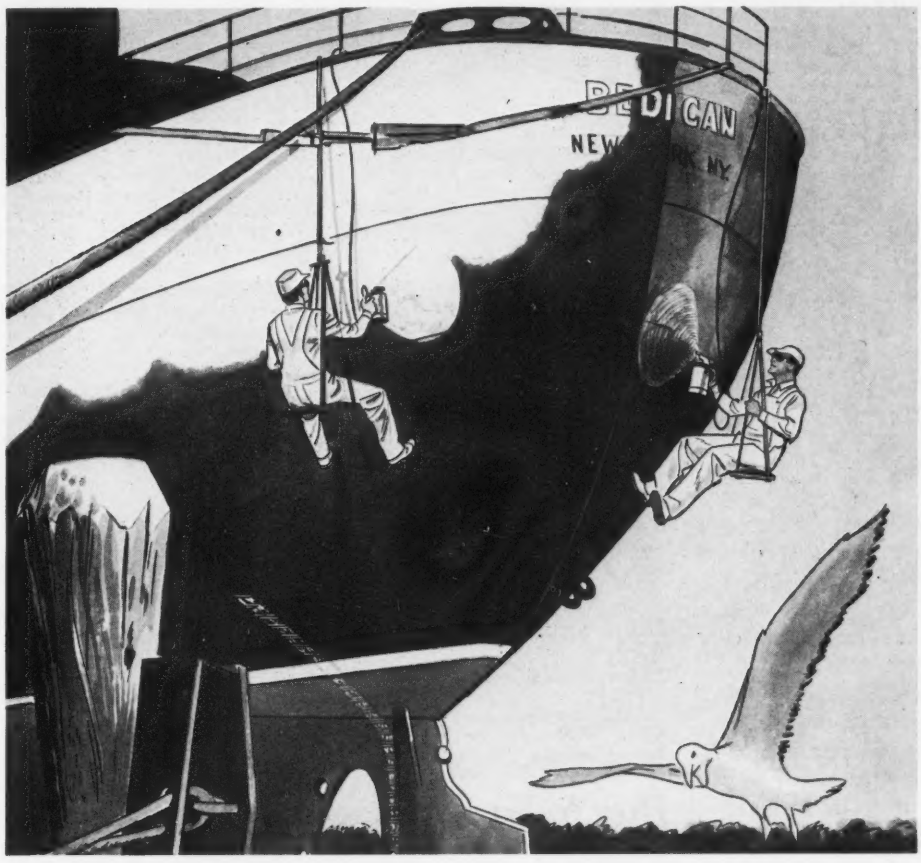
Tulsa Section Corrosion Short Course Feb. 13-15

Tulsa Section's Eighth Annual Corrosion Short Course for Pipeliners will be held February 13-15 at the Mayo Hotel, Tulsa. O. W. Everett, Oklahoma Natural Gas Co., 5848 East 15th St., Tulsa is general chairman of the course.

1957 General Business Meeting Time Changed

The 1957 general business meeting of NACE will be held at St. Louis beginning at 11:30 am, Wednesday, March 13. All other association activities at the conference will end at 11:20 am so members may attend.

Formerly the general business meeting has been held on the opening day of the conference.



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SOUTHEAST REGION'S November 7-9 meeting at Charlotte, N. C. had a special day honoring Dr. Ivy M. Parker, Plantation Pipe Line Co., Atlanta CORROSION's editor for the past 12 years. She is seated on the left of E. P. Tait, Alloy Steel Products Co., Atlanta, Southeast Region director. On Dr. Parker's left are seated Rodney Teel, International Nickel Co., Inc., Wrightsville Beach, N. C., chairman of the Carolinas Section; Mrs. Teel and Fred D. Stull, Texas Gas Transmission Co., Owensboro, Ky.



SOCIAL HOUR honorees during the Southeast Region meeting at Charlotte were: left, Mr. and Mrs. H. W. Ross. Mr. Ross, chairman of Birmingham Section, is with Ross Henderson Co., Birmingham, Ala. Right, Mrs. Teel pins an ivy leaf on Rodney Teel in honor of Dr. Ivy M. Parker.

How to Save Dollars Was Theme of Southeast Region's Meeting at Charlotte November 7-9

Corrosion in Industry and How to Save Dollars was the theme of the November 7-9 meeting of Southeast Region at Charlotte, N. C. The meeting designated November 8 as Dr. Parker Day in honor of Dr. Ivy M. Parker, editor of CORROSION. She was honored additionally by distribution of ivy leaf bouquets to ladies attending the social hour and banquet.

About 100 persons registered for the two-day event, which featured formal papers and discussions on corrosion theory, paper and pulp industry corrosion problems, steels for inside and outside use, aluminum alloys, nickel and nickel alloy welding materials, stainless steels, painting and painting practices, coating economics and other technical subjects.

Social events included a fellowship hour and banquet and attendance at an ice hockey game following the banquet.

Also on the program was a tour of the Application Development Laboratories for Synthetic Fibers of the Celanese Corp.

Meetings of Regional officers and Carolinas Section officers were held November 7. An election of officers for Carolinas Section also was scheduled.

Committee Thanked

Work of the arrangements committee was praised by Rodney B. Teel, International Nickel Co., Inc., Carolinas Section chairman. Members of the committee were Harold Kandell, John Manning, and R. D. Williams, Celanese Corp. of America; Jack Paylor, Piedmont Natural Gas Co.; Mr. and Mrs. J. S. Livingstone, Livingstone Coating Corp.; Ray Penrose, Aluminum Company of America and Emmet H. Steger, Sherwin-Williams Co.

Miss Martha Randall, Miss Charlotte of 1956 handled registration.

Contributors to the social hour were Alloy Steel Products Co., Aluminum Company of America, Anti-Corrosion Manufacturing Co.; Barrett Division, Allied Chemical & Dye Corp.; Celanese Corp. of America, Crutcher-Rolfs-Cummings, Dearborn Chemical Co., Electro Rust-Proofing Corp., Industrial Piping Co., International Nickel Co., Inc.; J. A. Jones Construction Co., Koppers Company, Inc.; Louisiana-Mississippi Pipeline Construction Co. of N. C.; Livingstone Coating Corp., Midwestern Pipeline Products Co., Reilly Tar & Chemical Co., Rosson-Richards Co., Royston Laboratories, Inc.

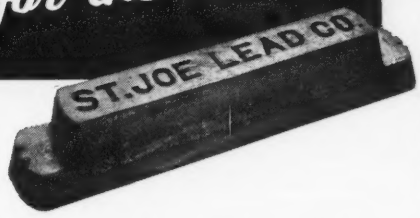
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A Job for Chemical Lead



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A method of protecting lead-lined vessels under high temperature conditions is to cover the metal with an inner lining of special acid-resistant brick. The installation shown above is a sulfuric acid concentrator, 16 ft. in diameter and 24 ft. high. Some 19 tons of chemical lead were used in lining the vessel. This type of construction is used commonly in the 450°F range and has been used at higher temperatures. The brick lining provides a temperature gradient to insulate the lead. Since no aggregate material can be entirely impervious to seepage, the corrosives leaking through are stopped by the lead lining and thus prevented from destroying the steel supporting structure. *Photo courtesy Chemsteel Construction Co., Inc.*

TYPICAL ANALYSIS OF ST. JOE CHEMICAL LEAD

Silver	.0100%	Arsenic-Antimony-Tin Combined	.0002%
Copper	.06		
Bismuth	Nil	Cadmium	.0002
Zinc	.0001	Cobalt & Nickel	.0046
Iron	.0001	Lead by difference	99.92+

Among the common metals, lead has no equal in its value to the chemical industry as a construction material for handling and controlling corrosives. The metal's utility in this field is well documented by a wealth of available performance records. The protection afforded by lead is the end-result of an inherent chemical property which is unique with the metal. Exposed to most corrosives, lead automatically forms upon its surface an insoluble, tightly adherent film of salts which henceforth acts as an effective barrier against further corrosion. The uncommon property of the common metal lead to forge its own protective armor is the reason why more than one-third of all the lead consumed annually in this country is used primarily for its resistance to corrosion.

St. Joe Chemical Lead is the most extensively used brand of lead in the chemical industries. Hundreds of thousands of tons are now in use—especially where operating conditions are severe. The metal is an exclusive product derived from the huge ore bodies of southeast Missouri which have been owned and operated by this Company since 1865. Owing to the unusual nature of these ores, there is present in the lead smelted from them a combination of copper and small amounts of other elements which produces a grade of lead particularly immune to the attack of most corrosives. At the same time, this natural chemical lead has a lower creep rate and a higher resistance to fatigue failure than lead produced from any other ores.

ST. JOSEPH LEAD COMPANY

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Committeemen Named for Oklahoma City Meeting

Principal committeemen have been named for the October 1-4 meeting of South Central Region at Oklahoma City. Dan Carpenter, Aquaness Department, Atlas Powder Co., general arrangements chairman listed the following committee chairmen:

Eddie G. Kessler, Kerr McGee Oil Industries, assistant general arrangements.

C. C. Allen, Anderson-Prichard Oil Corp., local arrangements.

Joseph D. Alcott, Anderson-Prichard Oil Corp., assistant local arrangements.

Frank B. Burns, Kerr-McGee Oil Industries, finance.

John A. Knox, Halliburton Oil Well Cementing Co., entertainment.

E. G. Stevens, Dowell Inc., publicity.

M. F. Hill, Greene Brothers, Inc., assistant publicity.

M. L. Steffens, Oklahoma Natural Gas Co., registration.

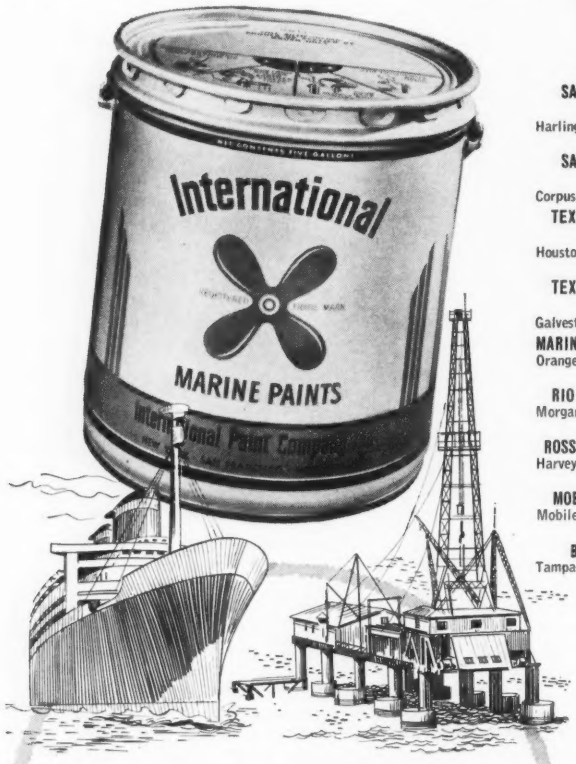
Mrs. Dan H. Carpenter, Box 8521, Oklahoma City, ladies' program.

George W. Evans, Southwestern Bell Telephone Co., printing.

Truel E. Adams, Consolidated Gas Utilities, assistant printing.

R. D. McDonald, Oklahoma Natural Gas Co., properties.

W. C. Koger, Cities Service Oil Co. and L. A. Hugo, Phillips Petroleum Co., co-chairmen technical program.



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TEXAS MARINE & INDUSTRIAL SUPPLY CO.
Houston, Texas
Phone: WAlnut 6-1771

TEXAS MARINE & INDUSTRIAL SUPPLY CO.
Galveston, Texas-----Phone: 5-8311

MARINE & PETROLEUM SUPPLY CO.
Orange, Texas
Phone: 8-4323—8-4324

RIO FUEL & SUPPLY CO., INC.
Morgan City, Louisiana
Phone: 5033—3811

ROSS-WADICK SUPPLY COMPANY
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Western Region Honors Members for Service

Concurrent symposia were held for the first time at any West Coast NACE meeting during the November 15-16 Western Region Sixth Annual Corrosion Conference at Long Beach, Cal. Registration for the conference was 185. The two-day short course held 13-14 under the sponsorship of Western Region and the University of California at Los Angeles had 135 registered.

Preston W. Hill, Signal Oil & Gas Co., was general chairman of the conference.

W. F. Fair, Jr., Koppers Co., Inc., Pittsburgh, NACE president gave a talk at the conference on accomplishments in corrosion control. The text of this address appears elsewhere in this issue of CORROSION.

Past Officers Honored

Regional merit award certificates were presented to members whose service to the region has been outstanding. At a cocktail hour and banquet at Hotel Lafayette, awards were presented to:

L. L. Whiteneck, Plicoflex Corp. and Israel Cornet, University of California for outstanding service to the region.

Past regional chairmen who received certificates were D. T. Jones, Pacific Telephone & Telegraph Co., North Hollywood, Cal. (1950); L. L. Whiteneck (1951); W. M. Schilling, Southern Counties Gas Co., La Habra, Cal. (1952); E. H. Grizzard, Signal Oil & Gas Co., Los Angeles (1953); R. H. Kerr, Southern California Gas Co., Los Angeles (1954); R. S. Treseder, Shell Development Co., Emeryville, Cal. (1955) and Preston W. Hill (1956).

Short Course Program

Practical aspects of underground corrosion for non-technical personnel were covered at the short course. J. S. Dorsey, Southern California Gas Co.; J. C. Dillon, University of California at Los Angeles and Israel Cornet, University of California at Berkeley were in charge of the course.

W. M. Henderson, president of the Los Angeles chapter of the American Public Works Association acted as chairman for one of the sessions.

R. E. Hall, Union Oil Co. was program chairman for the corrosion conference following the short course. L. E. Magoffin, California Water and Telephone Co.; C. E. Schillmoller, International Nickel Co., Inc.; Lester Morris, Coating and Fiber Glass Research Co. and R. H. Kerr, Southern California Gas Company conducted sessions during the conference.

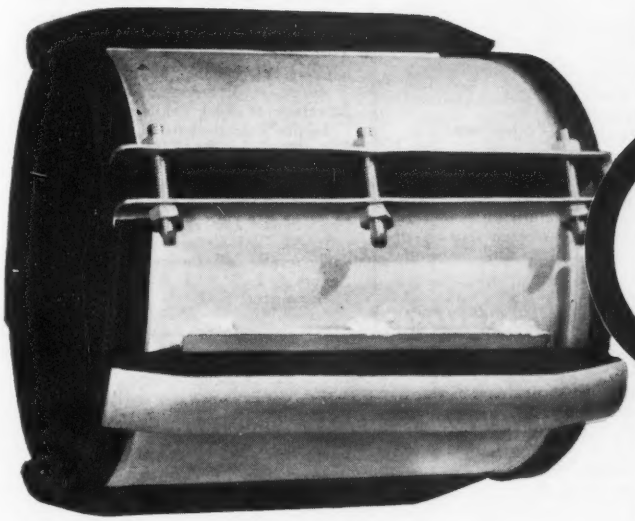
An informal dinner was held November 14 to permit discussions among regional and section officers and Dr. Fair.

Gibson Elected Chairman Of Alamo Section for 1957

J. W. Gibson, D. W. Haering & Co., Inc., San Antonio was elected chairman of Alamo Section, effective December 1 for a term of 13 months. Zane V. Morgan, Texas Acidizers, Inc., Seguin was elected vice-chairman. Because procedure for election of a trustee is not included in section by-laws Max F Schlather, United Gas Pipe Line Co. will continue to serve in that capacity until his successor can be elected.

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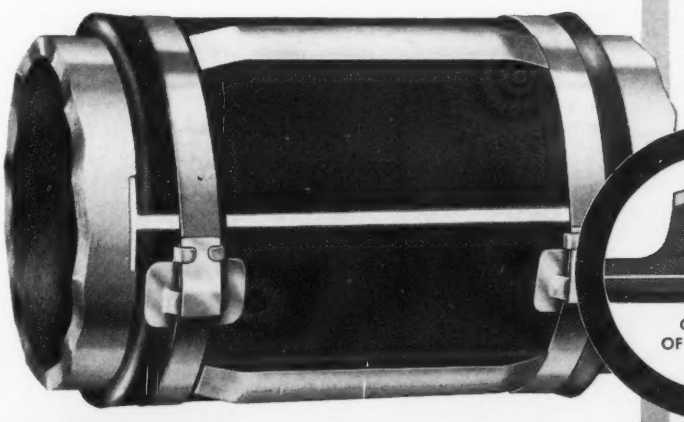


THE MALONEY MODEL 55 CROSSING INSULATOR FOR ALL SIZES OF PIPE

These insulators have superior insulation qualities because of the low moisture absorption and the long life compounded into the Neoprene. The wide steel, sled type runners make installation easy. The extra wide band affords a positive grip.

Bonded metal-to-Neoprene-to-metal, the runner insulates and also permits flexibility to compensate for pipe shifting and acts as a shock absorber to prevent damage due to sudden heavy loads.

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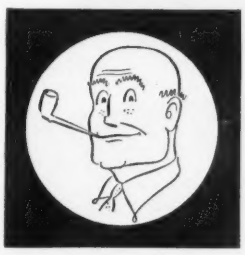
THE MALONEY MODEL 56 CROSSING INSULATOR 2" TO 12"

Manufactured with Neoprene, which is vulcanized to steel band core and to the rounded steel runners, there is no place to "short-out" between the casing and the carrier line. The steel core is completely surrounded with Neoprene.

Shipped flat, the Insulator is banded to the carrier pipe with stainless steel bands.

Manufactured in sizes from 2" thru 12", it can be used either on installations where there is only one nominal pipe size difference or on installations having a larger differential.

This is the Insulator designed and manufactured to give you the best job at a competitive price.



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North Central Region Elects R.W. Flournoy

R. W. Flournoy, Corn Products Refining Co., Argo, Ill., has been elected chairman of North Central Region at a November 16 meeting in Detroit. Also named were W. E. Hare, Hare Equipment Co., Cincinnati and R. C. Weast, Case Institute of Technology, Cleveland, respectively, vice-chairman and secretary-treasurer.

Section trustees have been designated as follows:

Chicago—C. A. Van Natta, Plastic Lining Coatings.

Cleveland—B. Husock, The Harco Corp.

Detroit—N. A. Kerstein, Detroit Edison Co.

Eastern Wisconsin—L. C. Wasson, A. O. Smith Corp.

Greater St. Louis—A. Orman Fisher, Monsanto Chemical Co.

Kansas City—W. W. Hoover, Jr., Koppers Co., Inc.

1957 Officers Elected By Northeast Region

The following officers have been elected to serve the Northeast Region for 1957: J. D. Bird, The Dampney Company, Boston, Mass., chairman; E. L. Simons, General Electric Company, Schenectady, New York, vice-chairman; J. P. G. Beiswanger, General Aniline and Film Corp., Easton, Pa., secretary-treasurer; F. E. Costanzo of Manufacturers Light & Heat Company, Pittsburgh was elected Northeast Region Director to take office effective the last day of the Conference in St. Louis, March 15, 1957 and to serve through March 1960.

Nine Symposia Scheduled For Meeting in Chicago



Moorman

Nine symposia are proposed for the October 1-4 North Central Region meeting in Chicago. First day of the meeting has been reserved for meetings of technical committees.

The nine symposia projected are: Protective coatings, transportation, pipe lines, cathodic protection, chemical process industries, refineries, H_2O treating, fundamentals and public utilities.

E. F. Moorman, International Harvester Co., Chicago, is chairman of the technical program committee for the meeting.

Northeast Fall Meeting Dates Are Changed

Because of conflict with meetings of other organizations the fall meeting of Northeast Region has been rescheduled for November 12-14. It previously had been set for October 7-9.

The meeting, to be held at the Penn-Sheraton Hotel, Pittsburgh will have R. B. Hoxeng, Applied Research Laboratory, U. S. Steel Corp., Monroeville, Pa. as general chairman and J. M. Bialoski, Koppers Co., Inc., Verona Research Center, Verona, Pa. as chairman of its technical program committee. John H. Royston, Royston Laboratories, Blawnox, Pa. is publicity committee chairman.

Articles Scheduled for February Publication

The following technical articles are scheduled for publication in February CORROSION:

Evaluation of Cooling Tower Corrosion Inhibitors, Charles B. Friedman and W. L. Denman.

Casing Corrosion in the Petroleum Industry, Jack L. Battle.

Coatings for Crude Oil Tank Bottoms, R. M. Carter.

Sprayed Metal as a Base for Paints, H. S. Ingham.

Cathodic Protection of the Coated Steel Gas Main Distribution System in New Orleans, Sidney E. Trouard.

Cathodic Protection of an Active Ship Using a Trailing Platinum-Clad Anode, H. S. Preiser and F. E. Cook.

Selection of Rust Inhibitors to Meet Service Requirements, A. J. Freedman, A. Dravnieks, W. B. Hirschmann and R. S. Cheney.

Embrittlement of 12 Percent Chromium Steel, H. Howard Bennett.

High Silicon Iron Anodes—A Report of NACE Task Group T-2B-4.

Bibliography of Corrosion Products—Part 1, 2, 3, 4, 5. A Report of Unit Committee T-3B.

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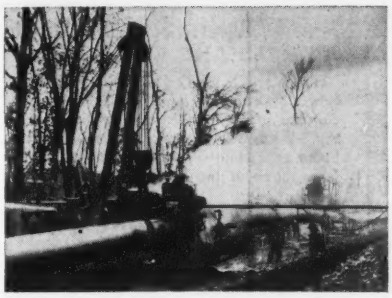


Photo showing Nicolet Felt Protecting Pipeline

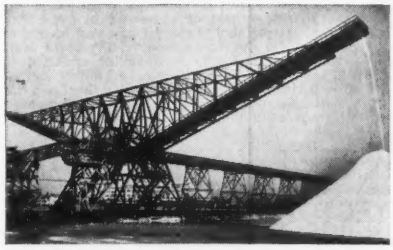
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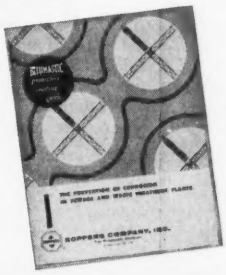
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19 Years of Protection were given this giant gantry crane at a salt-producing plant by a coating system of Bitumastic Super Service Black. Exposed to the corrosive combination of salt plus atmospheric moisture, the coating system has required only minor touch-up in all these years of service. Bitumastic Super Service Black is one of seven Bitumastic coatings; the complete line offers wide flexibility in the selection of corrosion-preventive materials to best meet the individual requirements of your application.



Corrosion Control in sewage and waste treatment plants is the subject of a new bulletin now available from Koppers. It contains complete engineering specifications for protective coating systems. Please request your copy on company letterhead from Koppers Company, Inc., Tar Products Division, 1455 Koppers Building, Dept. 100A, Pittsburgh 19, Pa.

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CUT CORROSION LOSSES
a report by Koppers Company, Inc.

Number 8 of a series



F. R. Charlton
Development Group Supervisor

An ideal coating possesses the ability to adhere tenaciously to a metal surface directly. Coal-tar enamels will provide such a bond when the surface is preheated. However, enamels applied directly to metal surfaces at normal temperatures chill too quickly and a poor bond results.

* * *

To overcome this problem, enamel primers of modified coal-tar pitch in suitable solvents were developed. When hot enamel is applied over a thoroughly dry, solvent-free pitch film, the primer melts slightly and produces a welded system—primer to pipe and enamel to primer.

The drying time of enamel primers is directly related to the volatility of the solvent and the environment. If hot enamel is applied to the primer before it is completely dry, the traces of solvent will destroy the bond to the enamel. Conventional practice is to prime one day and enamel the next, although this waiting period may be extended to several days or longer by poor drying conditions.

* * *

The Coatings Group at our Verona Development Laboratory recently studied this problem from a fresh point of view. They searched for a new base material, other than coal-tar pitch, which (1) would be compatible with the enamels, (2) would permit employing more volatile solvents, and (3) would provide a superior bond. After thorough study, a number of new formulations were tested. One met the requirements; it is called Bitumastic® Jet-Set.

Bitumastic Jet-Set is an entirely new kind of primer. It is formulated from special, plasticized resins which permit the use of low-boiling solvents and are compatible with coal-tar enamel. Bitumastic Jet-Set exhibits remarkably low temperature susceptibility and excellent resistance to chemical environments and moisture.

The drying rate of Bitumastic Jet-Set is truly amazing. It dries to touch in from 1 to 15 minutes and is ready for enameling in a maximum of 8 hours; conventional primers under similar conditions require several days to dry adequately.

* * *

Bitumastic Jet-Set opens up entirely new opportunities for the application of coal-tar enamel. Field experience has proved that the fast-drying characteristic of this new primer saves time and actually permits work to continue where heretofore, conventional primers have necessitated shutdown. Another application, where piling was driven after being enameled, demonstrated the excellent bonding ability of Bitumastic Jet-Set.

Complete data on this new primer is available. Ask your local Koppers representative, or write Koppers Company, Inc., 1450 Koppers Building, Department 100A, Pittsburgh 19, Pa. District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh, and Woodward, Ala. In Canada: Koppers Products, Ltd., Toronto, Ont., and Edmonton, Alta.

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COATINGS AND ENAMELS

Fair Discusses NACE Progress and Gains Made In Corrosion Control During Recent Months

The following address, "Trends in Corrosion Prevention," was given by Dr. Wm. F. Fair, Jr., Tar Products Div., Technical Section, Koppers Co., Pittsburgh, Pa. at a meeting of Western Region National Association of Corrosion Engineers, Long Beach, Cal., November 15, 1956. Dr. Fair is president of NACE.

IN THE DOMAIN of methods and materials for corrosion prevention, the National Association of Corrosion Engineers as an organization, and our individual engineer-members, have maintained prominence during the past year.

NACE has continued its sound growth and is anticipating further increase in membership in the future. Total membership now is 5600, of which 400 are corporate members. Additional support by industry, as indicated by an increase in corporate membership, would be most gratifying both for financial and morale considerations.

It appears that care and diligence on the part of our executive secretary and his staff will permit us to finish the 1956 fiscal year slightly in the black, rather than dropping to the small deficit which a year ago appeared to be unavoidable.

Officers of the association have worked to strengthen NACE organizationally, financially and technically on a national scale, and without exception have given freely and ungrudgingly of their employers' time and expense funds to accomplish these objectives.

The six regions now comprise some 53 sections providing for interest and stimulation in corrosion matters on broad and on local levels.

More Technical Committees

The six technical group committees are flourishing and are becoming nationally influential. Another group committee, T-7, on coordination of electrolysis

(Continued on Page 124)

Four Added to NACE Editorial Committee

Four members have been added to the Editorial Review Sub-committee of the NACE Publication Committee. The addition brings to 13 the number on this committee which handles the review of technical articles published in CORROSION's Technical Section. The growing work of the committee, which has E. V. Kunkel, Celanese Corp., Bishop, Texas as chairman, necessitated the additions.

Persons added were:

A. L. Alexander, Head, Protective coatings Branch, U. S. Naval Research Laboratory, Washington, D. C.

Philip M. Aziz, Aluminium Laboratories, Ltd., Kingston, Ont.

Fred M. Reinhart, National Bureau of Standards, Washington, D. C.

John J. Halbig, Senior Research Engineer, Armco Steel Corp., Middletown, Ohio.

Members of the committee annually consider the hundreds of technical manuscripts submitted for publication in CORROSION.

AMENDMENTS TO NACE ARTICLES AND BY-LAWS

The Articles of Organization and By-Laws of the National Association of Corrosion Engineers were published in the March 1952 issue of CORROSION. Since that time three amendments have been made in the by-laws as follows:

1. **At a meeting on March 19, 1954 the board of directors approved an amendment to the NACE by-laws increasing active membership dues from $7.50 to $10.00. The amendment, effective January 1, 1955 was to Section 1, Article 11, of the by-laws that became effective March 11, 1951.**
2. **At a meeting on December 3, 1954 the board of directors approved a recommendation of the Policy and Planning Committee amending Section 2, Article I, of the NACE by-laws that became effective March 11, 1951 as folows:**
   All Applications for membership shall be forwarded to the Secretary and upon a finding by the Secretary that an applicant's qualifications conform with standards and membership requirements of the Association, membership shall become effective immediately upon payment of dues. If in the judgment of the Secretary, the eligibility of any applicant for membership shall be uncertain, such applicant's application shall be referred by the Secretary to the Executive Committee and an affirmative vote of a majority thereof required for election to membership.
3. **The Board of Directors by letter ballot dated April 25, 1956, approved an amendment to the NACE by-laws consisting of the addition of a new paragraph designated as Section 5, Article III, of the By-Laws that became effective March 11, 1951:**
   Exhibitions held or sponsored by regions or sections shall have the approval of and be under the management of the Board of Directors including the handling of formal contacts with prospective exhibitors and contracts for exhibit space by the Executive Secretary of NACE. The proceeds from such exhibitions shall become a part of the funds of the Association.

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Electrolytic corrosion is the biggest single destroyer of buried or submerged metal structures and pipelines.

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Permits high-speed wrapping... assures effective protection for coating.

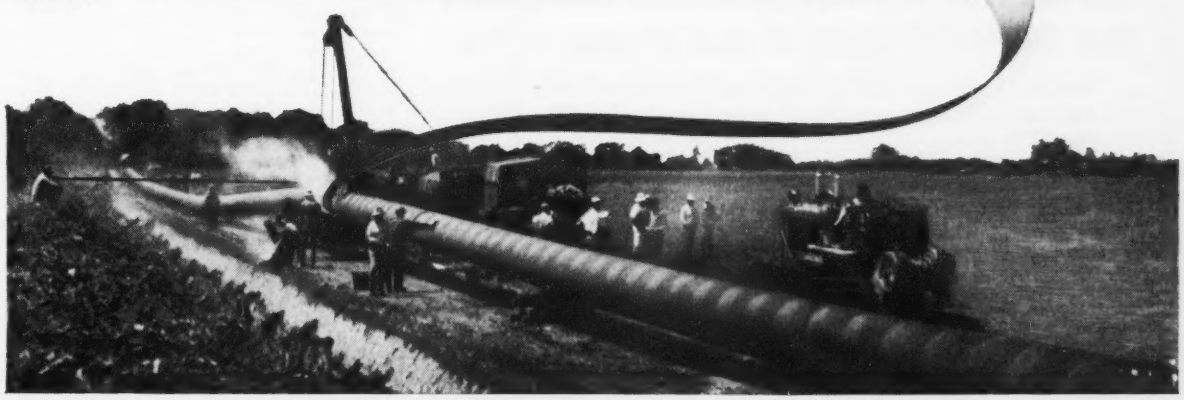
Transhield gives high value for a reasonable cost . . . made of tough, long-life asbestos reinforced with parallel glass yarns . . . it forms a continuous sheath between the enamel coating and the soil to guard against soil stress and give long life to the pipe line coating.

Contractors like Transhield's light weight and easy application . . . it speeds up coating operations . . . the high tear strength (a knife is used to cut it) and 800-ft. rolls lower construction costs.

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American Louisiana Company's pipe line runs from Cameron, Louisiana to Detroit, Michigan, with a 22" tie line from Defiance, Ohio to Bridgman, Michigan. In the stretch from Southern Louisiana and Willow Run, it crosses eight states and nine major rivers and lakes

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Fair Discusses—

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problems in different geographical localities was established following the prescribed petitioning by a group of interested members. Consideration is being given to the formation of two more group committees. One probably would concern the needs and future activities of the marine borer conferees. Another new phase of committee work deals with active interest in stray or induced AC currents. At present there are over 100 unit and task committees most of which, under able chairmen, are seriously working on corrosion problems assigned to them by one of the six parent group committees. Over 1000 persons are now active in technical committee work.

During the past decade there has been increased attention to corrosion prevention in industrial and in engineering fields. During the past few years it is gratifying to learn that many engineering schools are now including corrosion courses in their curricula.

Short Courses Spur Interest

In this connection, the activities of technical societies, and particularly the short courses sponsored jointly by NACE and universities in different parts of the United States, Canada and Mexico during the past eight years, have been a big factor in awakening interest simultaneously in industrial and academic circles in the field of corrosion prevention. About 40 courses have been given during this time.

Somewhat allied with educational trends in corrosive engineering is the recognition of the importance of the corrosion engineer and his control methods. The American Standards Association code provides means through the objectives of which the corrosion engineer may insist on corrosion control. At the same time, more and more instances are observed where the corrosion engineer has been able to convince management of major companies of the necessity of corrosion prevention. Helping the engineer in this important advance professionally has been the availability from manufacturers of better corrosion preventive materials and technical information concerning the application and performance of such materials.

The distinct change in management point of view in regard to corrosion engineering is most encouraging. The development of a cost of corrosion consciousness on the part of management is an outstanding accomplishment of NACE. The field is becoming recognized as a specialty requiring the services of trained professional men to whom prestige and authority should be granted according to their accomplishments.

It is hoped and believed that solid foundations are being laid which will enable the next administration to strengthen NACE rapidly in all our dedicated activities.

Certain avenues of approach are currently of potential importance for future corrosion control practices.

Solar Energy Is Important

At the American Chemical Society 75th Anniversary Meeting, Dr. J. B. Conant in a forecast of future activities suggested that solar energy would prove to be more important to mankind than would nuclear energy. He pointed out that fissionable by-products of nuclear energy generation plants could make nearby territories unfit for occupancy. Solar energy, efficiently applied, might be used to distill sea water, which then could be used to irrigate arid but fertile lands, transforming them into areas of great food productivity believed necessary for the tremendous population growth expected during the next century.

During the past several weeks I have corresponded with several friends in NACE, asking their opinions on important current trends in corrosion prevention. Their replies have given me information on the fields of activities here described briefly.

Nuclear Energy

As indicated above, many corrosion engineering problems may be encountered here. Reactor problems are many, including fuel handling, piping, sealing, effluent lines and disposal of fissionable by-products. Nuclear energy plants need stable protective coatings and these coatings must have the property of being easily decontaminated. Special alloys, resistant to deterioration under service conditions generally are specified throughout these plants.

Important questions in this field for the corrosion engineer deal particularly with deterioration by radiation and more particularly with the grave problem of disposal or storage of the radioactive fissionable waste products, some of which have half-lives of up to 100 years.

Recent news reports have speculated upon emergency danger through accident in the field of nuclear energy generation. Safety controls presumably are being built into the large power plants now under construction in this country. Other questions will arise when such generators are put in mobile units such as railroad locomotives or ocean going vessels. In case of a wreck of an atomic powered locomotive, the results might be disastrous, unless appropriate safety provisions are integrated.

Already there are two atomic powered submarines and plans are being discussed, according to the newspapers, for construction of commercial vessels powered with nuclear generators. In case of shipwreck, it has been suggested that radiation would affect plankton, which when eaten by fish, might cause the retention of radioactive elements, which in turn might result in dangerous build-up of such elements in human beings.

We should all consider these advances seriously and not permit ourselves and others to be frightened unduly by careless or illogical conclusions.

I hope I do not sound like the doting mother who finally allowed her darling child to attend public school. She gave the teacher a long list of instructions. "My little Harold is so sensitive," she explained. "Don't ever punish him. Just slap the boy next to him. That will frighten him."

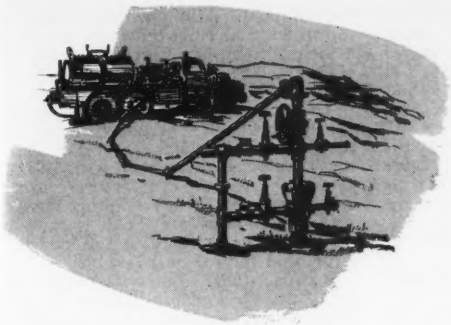
Neither do I think it cricket of the British to carry out recently announced plans to dispose of radioactive wastes in the Irish Sea!

On the other hand, a good use of the powerful instrument now available may be illustrated by the beneficial effect of control radiation as a supplement to insecticide application, according to S. Jefferson of the Atomic Energy Research Establishment in England. In the Island of Curacao it was found that screw-worm flies could be reduced to a low level of population by the application of insecticides. However, when the treatment was withdrawn, the few remaining insects quickly multiplied and regained nuisance level. Knowing that the female fly mates only once, it was decided to try the effect of flooding the area with radiation-sterilized male flies. The flies were specially bred, sterilized by radiation from a genetic point of view and then released when the fly population had been depressed by insecticide. The technique was so successful that the pest was completely eliminated from the island.

According to Love and White in a recent paper in INDUSTRIAL AND ENGINEERING CHEMISTRY (Vol. 48, 1248, August, 1956) water for nuclear engineering

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REPORT ON A NEW CONCEPT IN CORROSION CONTROL

For Oil and Gas Wells

CORBAN®, the polar-type corrosion inhibitor developed by Dowell, has proved its effectiveness in hundreds of wells. Now, a different concept in the use of liquid inhibitors has been developed. In this method, Corban is not merely put in the well; it is pumped back into the producing formation. Then it returns slowly to the well bore along with normal oil production. Continuous protection is thus given to all metal equipment for a period of months.

So far, results have been outstanding. The following case history is an example of the results obtained with this new method.

A gas-lift well in South Texas was producing 25 BOPD and 85 BWPD from the Frio sand. The well was equipped with 1-inch tubing containing gas lift valves inside 2½-inch J55 production tubing. The 1-inch tubing extended to a depth of 2001 feet; total depth of the well was 5547 feet. A packer was set at 5482 feet. At 2468 feet, the 2½-inch tubing was swaged to 2-inch tubing. Severe corrosion was found to be at the swage, 467 feet below the bottom of the 1-inch tubing. It was doubtful that inhibitor applied in the conventional manner would reach even the bottom of the 1-inch tubing.

Corban was then pumped into the formation. Ten gallons of concentrated Corban 101 were mixed with 12½ barrels of salt water. Since this one treatment, water produced by the well has been analyzed several times. The following table shows the results.

Date	Iron, Parts Per Million	Remarks
4- 6 -56	132	Just prior to described treatment
4-11-56	41	First test after treatment
4-17-56	80	Second test after treatment
4-25-56	55	Third test after treatment
5-14-56	27	Fourth test after treatment
6- 6 -56	23	Fifth test after treatment Iron content reduced 83% at this time
9- 1 -56	37	Sixth test after treatment Iron content still reduced by 72% compared to that before treatment

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Compare these results with conventional methods

Services for the oil industry

DOWELL

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Fair Discusses—

(Continued from Page 124)

will constitute a grave problem in the future. In solving these problems, corrosion engineers undoubtedly will be called upon to play their parts along with the development engineers and nuclear physicists. Love and White point out that the outlook for adequate supplies of water of suitable quality for nuclear energy development is more favorable in some parts of the country than in others. Competition for water in some areas is intense and may pose real limitations on the development of nuclear installations.

Development engineers and other scientists responsible for expansion of nuclear engineering projects are urged to give early and thorough attention to water requirements with reference to existing or potential availability of water supplies. The program of waste disposal from nuclear installations also must be planned carefully so that receiving streams and underground waters will not be rendered dangerous or unsatisfactory for subsequent use.

It is imperative that leaders in the field of nuclear engineering lend their support and actively participate in programs that have as their objective the development and conservation of water supplies for all beneficial uses including expansion of nuclear energy installations.

Water Supplies and Transportation

Potable water must be supplied to our increasing population. This should mean progressive planning for years ahead to procure and deliver water to the centers of population. Simultaneously our increased population will require enormously larger amounts of food, fibres and shelter. Production of such fundamental necessities will require expanded plant processing facilities which cannot function without adequate supplies of water of suitable quality for industry and for irrigation. Larger volumes and longer distances from source to consumption should lead inevitably to greater water pipe line construction.

Parallel with this must be the planning, construction and operation of sewage treatment and waste disposal plants. Recently it was estimated that during the next 20 years some $22 billion will have to be expended in sewage treatment plants alone.

Obviously such vast programs will present many challenges to technical and engineering groups, including corrosion engineers.

Metals

A promising development in the field of metals is in the technology of titanium and its alloys. Information on these products shows development work on their applications are being expanded at a tremendous rate. It is only sensible to expect that use of these materials in industrial applications should be studied extensively.

Thin Monel sheathing in thickness of the order of .037-inch has been used successfully for the protection of piping in tide and splash zones in salt water. Besides shore installations, this application is being used on some of the drilling platforms in the Gulf of Mexico and on the "Texas Towers" or radar platforms, in the Atlantic Ocean off the Northeast Coast.

It is stated that corrosion of Monel sheathing is negligible in this long term service, thus providing an economical means of protecting areas which are not amenable to cathodic protection and which are difficult to protect with conventional coatings.

Another attempt to obtain more efficient protection in this tide zone service has been the use of a jacket filled with gypsum in which are buried rods to provide cathodic protection from impressed current during the period of falling and rising tides.

Aluminum jackets around deteriorated piling, with tar-sand or asphalt-sand mixtures in the annular space, give increased life to old pier installations.

Special coatings have been developed also for sea water immersion service as described below.

In the field of spray metallized coatings, application of corrosive resistant alloys is included for protection and for rebuilding of corroded surfaces. It is said that fusing in place of properly selected combinations for special service conditions has just started. The possibilities are widespread but it is believed that considerable development work remains to be done.

A recent development which the manufacturers feel has intriguing possibilities is a product including a pipe with an integral steam trace. This should be of interest to corrosion engineers for the handling of molten sulphur, ammonium nitrate, urea and many other chemical substances which have to be heated for pipe line transportation.

Inorganic Inhibitors

Effective use of inhibitors at low concentrations in cooling water may be possible through combination of two or more inhibitors. Where the water throughput is large, this modification may be attractive economically.

It is claimed that significant protection also may be afforded by regular intermittent application where continuous contact with metal surfaces is impossible. This departure for inhibitor usage may prove to be technically valuable.

It is reported that evidence is available showing that fungus deterioration of wooden cooling tower structures can be minimized by a proper inhibitor, added primarily for corrosion penetration. Pressure-creosoted wooden structures generally are free from such attack. Erdalith treatment also has been found to be good in this service.

Effluent from refrigerator cars causes a corrosion loss of about $12 million annually by its effects on rails, bridges, tie plates and car parts. The need exists for non-toxic corrosion inhibitors to be used in conjunction with salt.

Diesel cooling water presents another inhibitor problem. Chromates are in a secondary status because railroads have had injury suits when personnel failed to practice proper safety procedures. The need for efficient non-toxic cooling water inhibitors is considered a pressing problem.

Corrosion inhibitors for lubricating oil for railroad roller bearings constitute another problem.

Organic Inhibitors

Use of organic inhibitors is expanding. They appear to offer an economical solution for oil-well corrosion.

A bottom hole dump bailer has been used to introduce concentrated inhibitors at the bottom of a well bore, ensuring complete coating with inhibitor from top to bottom. I am informed that treatment every 15 days costs about 1.6 cents per barrel of oil produced or 65 cents per million cubic feet of gas.

These products have found increased use in refinery operation, in storage tanks and in pipelines. Approved lists of these inhibitors have been issued for use in aviation fuels. Manufacturers are becoming interested in exploiting this field. These inhibitors are polar compounds which produce either a large basic or a large acid radical on hydrolysis.

Because these materials, as a class, are of the same general nature as emulsifying agents, caution must be used in their application. Inhibitors in production operations already have proved to be of great benefit; it is expected that wider use of inhibitors will naturally decrease corrosive losses in other phases of the petroleum industry.

Surface Preparation

Every year adds more conclusive evidence that good surface preparation—the best possible under the conditions prevailing—always should be specified and vigorously required. Sand blasting is almost universally preferred now.

Organic Coatings

Favorable reception and great interest is displayed in epoxy-coal tar formulations for cold application to pipe lines and other surfaces. Rapid curing is obtained from catalysts.

A need has existed for cold applied coatings which when used with suitable wrapper, such as glass fiber, can be applied at couplings and fittings and will set up in a few hours to a satisfactory hardness. Epoxy-coal tar products are finding use in this field. It is reported that this combination will resist higher temperatures than regular coal tar enamels. Wider use is anticipated.

These coatings appear to offer great promise to satisfy unusual conditions in the gas, oil and chemical industries. New developments are expected in this field and it is confidently expected that new types of this variety will be available in the near future. Their extreme toughness and chemical resistance to various corrosive environments offer great possibilities for application in all types of industries and in all kinds of conditions where severe corrosive conditions exist.

It has been reported that amine-cured epoxy coatings have performed well as internal coating for oil field piping. Short service results indicate that this material compares favorably with baked-on phenolic and baked epoxy phenolic.

Initial reports on the use of glass fiber and amine catalyzed epoxy wrappings for erosion-corrosion prevention in wells are promising. The same technique is being tried in the tidal zone on offshore structures. Coal tar-epoxy is being applied as a finish topcoat on these installations.

Special services in the pharmaceutical, chemical, and food product industries require the specification of carefully tailored coatings. The product may be of low pH but the cleaning solutions are of high pH. Product contact with the coating is at high velocity. It is vital that the coatings be homogeneously bound to the clean metal and that the bond continues through the entire coating thickness. The thickness of a heavy coating must be limited to that where

(Continued on Page 128)

TECHNICAL REPORTS

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given below for Book Post Registry to all addresses outside the United States, Canada and Mexico.

TP-1 Report on Field Testing of 32 Alloys in the Flow Streams of Seven Condensate Wells (Pub. 50-3) NACE members, $8; Non-members, $10 per Copy.

T-1A Survey of Corrosion Control in California Pumping Wells. A Report of T-1A on Corrosion in Oil and Gas Well Equipment, Los Angeles Area. Pub. 54-7. Per copy, $.50.

T-1C Current Status of Corrosion Mitigation Knowledge on Sweet Oil Wells. A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion. Per copy, $.50.

T-1C Field Practices for Controlling Water Dependent Sweet Oil Well Corrosion. A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion, Compiled by Task Group T-1C-1 on Field Practices. Pub. No. 56-3, Per Copy $1.00

TP-1D Sour Oil Well Corrosion. *Corrosion* August, 1952, issue. NACE members, $.50; Non-members $1 per copy.

TP-1G Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells. (Included in Symposium on Sulfide Stress Corrosion. (Pub. 52-3) $1 per copy. 5 or more copies to one address, $.50 per copy.

T-1G Sulfide Corrosion Cracking of Oil Production Equipment. A Report of Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking. Pub. 54-5. $.50 Per Copy.

T-1J Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. Per Copy $1.00

T-1J Reports to Technical Unit Committee T-1J on Oilfield Structural Plastics. Part 1, Long-Term Creep of Pipe Extruded from Tenite Butyrate Plastic. Part 2, Structural Behavior of Unplasticized Geon Polyvinyl Chloride. Publication 55-7. Per Copy $.50.

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T-4F-1 Progress Report of Task Group T-4F-1 on Water Meter Corrosion. Per Copy 50c

TP-5A Materials of Construction for Handling Sulfuric Acid. *Corrosion*, August, 1951, issue. NACE members, $.50; Non-members, $1 per copy.

T-5A A Bibliography of Corrosion by Chlorine. A Report of Technical Unit Committee T-5A on Corrosion in the Chemical Manufacturing Industry, Compiled by Task Group T-5A-4 on Chlorine. Publication No. 56-2. Per Copy $1.50

T-5A-5 Corrosion by Nitric Acid. A Progress Report by NACE Task Group T-5A-5 on Nitric Acid. Per copy, $.50.

T-5A-5 Aluminum Versus Fuming Nitric Acids—A Report by NACE Task Group T-5A-5 on Corrosion by Nitric Acid. Per copy, $.50

T-5B High Temperature Corrosion Data—A compilation by NACE Technical Unit Committee T-5B on High Temperature Corrosion. Publication 55-6. Per Copy $.50.

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TP-12 Report on Electrical Grounding Practices. Per Copy $.50.

TP-19 Corrosive Effects of Deicing Salts—A Progress Report by Technical Practices Committee 19. *Corrosion*, January, 1954, issue. NACE members $.50; Non-members $1 per copy.

Fair Discusses—

(Continued from Page 126)

the surface tension in the coating system will not be greater than the assembly adhesion of the coating system.

If these limitations are not considered, sections of coatings may split away from the metal in service. Each coating system has its own optimum thickness limit. Investigations currently are being initiated in this relatively new field.

Another development has resulted from attempts to apply thicker films without multi-coat application. Heavy bodied vinyl coatings are now available and are said to be applicable at from 10 to 20 mils thick in one application.

Hot spray methods also have been used to aid in application of greater thicknesses with a smaller number of coats.

The question of storage of demineralized water has become more important with the development of higher pressure boilers which require exceptionally pure water. Particularly objectionable is the occurrence of traces of silica. Silica, if present in concentrations above a few tenths of a part per million, will deposit on the tubes and blades and interfere with boiler operation and efficiency. One year immersion tests by a power company indicate that coal tar enamels can be used for demineralized water storage without contributing dissolved material to the water.

For storage tanks and tubular goods in the oil industry, baked-on phenols were the preferred coating in some circles. Recently epoxy modified phenolics have been used, also baked-on. Preliminary observations indicate that a more resilient film and better adhesion is obtained with the latter.

Air dried straight epoxy coatings, according to one report, have enjoyed mixed success in tubular goods.

Continued progress is being made in bitumen products containing asbestos fibers to produce protective mastic coatings. Highly thixotropic properties can be built into water dispersion combinations of this type, permitting spray applications of thick coatings without sag or dripping.

Fire retardant properties can be obtained in new bitumen compositions nearing final development in which the bitumen is highly chlorinated, and thus provides a fire retardant protective coating film upon drying.

In the field of more conventional paints, recent developments have been characterized by the utilization of new synthetic resins of high molecular weight composed of chemically resistant building blocks. Improved surface preparation requirements have been found necessary to realize maximum performance for these new coatings. Sandblasting is favored.

Paint users now accept 5 mils as an optimum film thickness. Some paint chemists question this since it does not appear logical that all types of paints exhibiting different flow properties and different chemical resistances should have identical film thickness. The corrosion committee of the Federation of Paint and Varnish Production Clubs has undertaken a research study of this problem.

Quick drying primers for use with pipe line enamels are being made available now. With conventional primers, which dry slowly under unfavorable weather conditions, coating application frequently has to be interrupted, sometimes for several days, because the primed surface is not dry enough to receive the hot enamel. New primers will prevent such work stoppages.

Hot Line Coatings

Conventional pipe line coatings do not withstand high temperatures at pipe surfaces of buried steam and hot water lines. Also, in some instances, there is need for thermoplastic coatings which can be used on hot oil or hot gas lines.

Insulation cannot be used on buried lines because of moisture absorption, which destroys thermal and electrical insulation properties.

Gilsonite in granular form recently has been used for this type of service. The material is poured into the ditch around the pipe and it is claimed that the heat from the pipe forms the granules into an impervious coating.

Special coal tar enamels have been developed by several manufacturers to provide coatings for hot product lines. These higher melting enamels withstand higher pipe line temperatures and are more resistant to soil stress. Results to date are most satisfactory.

Coal tar epoxy combinations are also being tried in this service.

Marine Immersion

Earlier investigation on the effect of cathodic protection on available coatings demonstrated without question that many types of coatings could not withstand moderate protective voltages in seawater. Bituminous materials are not deficient in resistance to moderately high protective currents, but can be affected by excessive voltages when immersed in seawater. Modifications have been made and tested during the past five or six years. Results indicate that cementitious outer coatings over protective coal tar coatings are effective in resisting barnacle penetration and that special hot applied coatings comprising coal tar enamels and selected hard sharp aggregates, not only are resistant to barnacle penetration but also have been found unaffected by excessive potentials during five years in seawater under practical service conditions.

These special coatings are applied to the piling from top to bottom before driving.

Soil Corrosivity

Aerated soil favors formation of protective rust films on metals while soils lacking oxygen prevent formation of protective oxide films. In the first condition, the corrosion rate drops rapidly, whereas under the second condition, there is no slowing down of corrosion. To provide a better means of evaluating soil corrosivity, the American Gas Association has sponsored development of a reduction-oxidation probe.

It is contended that redox measurements can be made before construction to guide the corrosion engineer in designing the proper level of corrosion mitigation. Currently, the probe is being used in the field to obtain data from which a curve correlating redox potential with soil corrosivity should be obtained.

Plastics

There has been much wider use of structural plastic materials. Plastic pipes, tanks and sheet material are said to provide good corrosion prevention for certain environments.

In the field of construction materials, these products are said to be still in the development stage. The type available offers resistance for oil field requirements but their structural behavior still leaves something to be desired. Development work is underway in an attempt to correct these defects. Plastic tanks have been reported to be too expensive and also lack performance stability.

Plastic tapes are being offered to compete with established pipe line coatings. The probable extent of such applications cannot be foretold at this time but it is interesting to note that at least two substantial trial applications are being made this year. Application, service performance and overall economics of such protective materials will determine their ultimate place in corrosion prevention planning.

Inorganic Coatings

Zinc-rich coatings recently have received concentrated interest. Some feel that the inorganic vehicle type offers the most attractive features in this field. Long term test service in seawater supports claims for good performance of this type of coating.

The zinc-rich paints now available are formulated with such a high zinc content (95 percent in the dry film), that electrical contact is maintained from zinc particle to zinc particle. Such primers are said to protect steel by galvanic action with sacrificial corrosion of the zinc dust. Reports from abroad have been varied on performance. Most reports in this country are favorable. Until further evidence is available, it would appear that correctly formulated products, properly applied over sandblasted surfaces, should give good protection in environments where the specification of such paints is practical.

Cathodic Protection

New materials are being developed which give the corrosion engineer greater latitude in the design of cathodic protection systems. These include high silicon cast iron anodes, aluminum-zinc alloy galvanic anodes and silicon rectifiers.

Field tests have shown that cast iron anodes have considerable promise for impressed currents. Further field tests and adoption by consumers are said to be necessary and imminent. This is reported to be the outstanding recent development in cathodic protection. A recent design provides for 2000 250-lb. zinc anodes interspersed among steel piles of a large pier in seawater. Expected output is 2000 amperes for a period of over ten years.

Appreciable progress also is being made in cathodic protection installations within large oil refineries.

Electrical utilities are installing pipe type cables for underground high voltage transmissional power. The insulated cables are drawn into a buried pipe line which is then filled with insulating oil or gas under pressures. The steel pipe is protected with enamel and grounded at each end for safety reasons. This grounding complicates cathodic protection and although modifications in the cathodic protection system have been proposed and installed, opportunity exists in this field for improved concepts.

An interesting development is the salt water grounding cell, for applying ca-

(Continued on Page 132)

A BELL RINGS

When it finds a "holiday" in any dielectric pipe coating.

† U. S. Patent No. 2,629,002
*Patents Pending



Model H-P

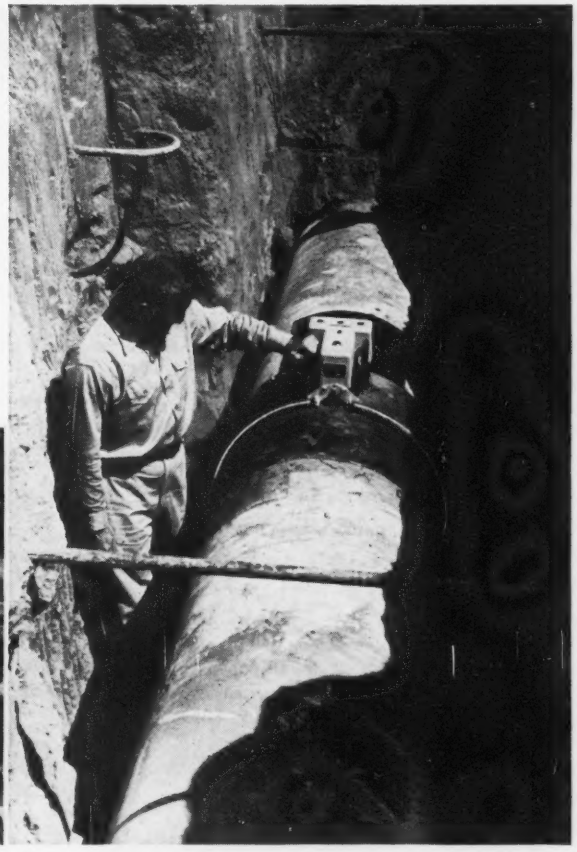
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Fair Discusses—

(Continued from Page 128)

thodic protection to power cable sheaths, to provide low resistance grounding in case of power faults.

Another development in this field has to do with deep ground beds designed to minimize cathodic protection coordination problems in crowded urban areas. Uniformly satisfactory results have been obtained in New Orleans, for example, where difficult local special terrain and corrosion problems exist.

Oilwell casings, sometimes called vertical pipe lines, formerly were buried without protection. Cathodic protection methods are now being accepted and external protective coatings are under consideration for this service. Here again the tar-epoxy products are receiving favorable comment.

Protection of water handling vessels currently is receiving much attention. Probable cost is estimated to be about $400 for installation and protection of a 100 barrel vessel.

In conclusion, the writer wishes to thank his many collaborators for their assistance and suggestions, and your arrangements committee for inviting me to take part in your regional meeting. Increased attention to better regional meetings I have urged for some years. Progress in this direction in all regions is unquestionable. This trend should turn out to be one of the more important facets of NACE.

South Central Region

According to a report filed by J. C. Spalding, Jr., secretary-treasurer of South Central Region the region had a balance on hand of $9005.42 as of October 21, 1956.

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Approx. Size

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GENERAL NEWS

Air Pollution Controls Cost One Plant $150 Daily

3-Day Session Held By Air Pollution Control Association

Controlling air pollution at one Houston area paper plant was estimated to cost $150 a day by Stephen Chase, Champion Fiber and Paper Company. Mr. Chase related the measures his company has taken and is taking to reduce the volume of air contaminant emitted from his plant.

Mr. Chase's talk was one of 21 presented during the December 2-5 meeting of the Air Pollution Control Association at the Rice Hotel, Houston. The meeting was the semi-annual technical meeting of the association. Papers presented covered a wide range of topics and industries concerned with air pollution problems.

Poison Gas Problem

Problems associated with the handling of nickel carbonyl gases were discussed by V. C. Henrich, Rohm & Haas Company. Mr. Henrich described precautions that are taken at his plant to prevent exposure of plant personnel to the poisonous fumes and how the air exhausted from the plant goes through a decontamination process.

Herschel M. Martin, Eastern States Petroleum Co. described some of the work his company is doing to control the smoke from flare gas. He described the way in which a smokeless flare was constructed at a minimum cost using a method involving spraying water into the flame.

A by-product of the solution, Mr. Martin reported was the production of large volumes of acidic water containing sulfur dissolved from the flare gases. Disposition of this water has been solved, he said, by mixing the water with waste caustic, thus neutralizing both.

Legal Efforts Recited

W. A. Quebedeaux, director, Harris County Stream and Air Pollution Control, opened the meeting with a discussion of his efforts to enforce air and stream pollution control measures. He indicated a fair degree of success was achieved in cases brought before the courts, but thaat some difficulty has been experienced because he must work through the offices of the county attorney.

Papers presented during the meeting included the following:

Control of Air Pollution at Champion Paper & Fiber Company, Karl R. Bendetsen.

Control of Fumes in Refinery Acid Treating, B. I. Bell, Sinclair Refining Co.

Air Pollution Control by a Sulfur Dioxide Scrubbing System, W. C. Lawler, Olin Matheson Chemical Corp.

Pollution Control When Unloading Acid Sludges, H. Zeh Hurlburt, Consolidated Chemical Industries.

Control of Fluorine and HF Discharges, John Stris, Nyotex Chemicals, Inc.

Control of Air Pollution from Insecticide By-Products, R. J. Koll, Diamond Alkali Co.

Hydrogen Sulfide Recovery and Use in a Refinery. R. A. Dudley, Humble Oil & Refining Co.

Control of NH_3 Fumes, W. E. Burns, Phillips Chemical Co.

Tanker Cleaning Methods Listed by API Committee

Recommendations on procedures for cleaning tankers in clean service have been made by the Advisory Committee on Minimum Tank Cleaning Requirements in a report dated June 14, 1956 on the American Petroleum Institute Tanker Corrosion Research Project. R. I. Lindberg, Sinclair Research Laboratories, Inc., is chairman of the committee.

In descending order of desirability the committee recommends:

1. No cleaning at all when contamination requirements can be met.
2. Use of eductors and blowers to remove residual cargo as an alternative to washing with water.
3. Bottom washing with hoses, line flushing and lifting of sediment.
4. Flushing with fresh water, preferably cold.
5. Flushing with cold salt water, followed by fresh water rinse.
6. Flushing with hot salt water followed by fresh water rinse.

In general the committees believe much washing can be avoided by proper scheduling of cargo sequences and that in any case much of the machine washing presently done is unnecessary. One ship has had no contamination in nine months of operation while using a seawater eductor to strip a tank followed by mechanical ventilation.

Manhattan Engineering Center Plan Approved

United Engineering Trustees, Inc., consisting of the American Society of Civil Engineers, American Institute of Mining, Metallurgical and Petroleum Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers has decided to construct a multi-million dollar engineering center in midtown Manhattan. Addition of the American Institute of Chemical Engineers to the trustees is under consideration.

Quarters presently occupied by the trustees and numerous engineering socities affiliated with them are to be abandoned because of overcrowding.

A nationwide drive for funds to construct the new center is in prospect.

Metallurgical Congress

The Second World Metallurgical Conference will be held in Chicago November 2-8, 1957. The meeting is sponsored by the American Society for Metals.

Enamels Resistant to Steam Condensate Tested

"Tests for Evaluating Resistance to Steam Condensate Attack," a paper by J. A. Schiefferle, General Electric Co. deals with efforts to find a porcelain enamel suitable for domestic clothes washer dryer units that will protect base metal against corrosion. This was one of numerous papers presented November 7-9 during the 18th Shop Practice Forum of the Porcelain Enamel Institute at University of Illinois, Urbana.

Mr. Schiefferle described tests made to determine the characteristics of porcelain enamel under laboratory conditions similar to those experienced in service. One test involved spark testing at 2000 volts. Tables of losses under several conditions of test are given.

J. M. Zander, Chicago Vitreous Corp. described advantages of batch spray pickling to prepare metal surfaces for enameling. His paper was titled "Automatic Spray Pickling."

Characteristics of low-temperature enamels designed for application to thin gauge aluminum sheets were explored in a paper titled "Properties of Low Temperature Porcelain Enamels," by H. P. Tripp, General Electric Co. The enamels showed considerably lower resistance to 5 percent caustic or tetrasodium phrophosphate solutions than conventional enamels.

Reactor Construction Code Urged at Standards Meet

National codes for atomic power establishments were urged by Morehead Patterson, chairman and president of American Machine & Foundry Co., in a speech before the Seventh National Conference on Standards at the Roosevelt Hotel, New York, October 24. The alternative is "an infinite variety of standards which will drive a reactor designer or manufacturer crazy if he tries to build in different localities," Mr. Patterson believes.

Presented at the conference were:

The U. S. Reactor Program—by Stuart McLain, program coordinator, Argonne National Laboratory, Lemont, Ill.

Present Nuclear Energy Standardization—Morehead Patterson.

Use of Nuclear Techniques in Industrial Testing, Dr. Charles Crompton, National Lead Co., Cincinnati.

Standardization and Atomic Energy by Vice-Adm. W. A. Kitts (ret), manager Atomic Products Study, General Electric Co., Schenectady.

Nuclear Congress Set

The 1957 Nuclear Congress, coordinated by the Engineers Joint Council, will be held March 11-15 at Philadelphia. Participating are five groups interested in atomic energy. Theme will be peacetime uses of atomic energy.

BOOK REVIEWS

Development of the Redox Probe. 23 pages, 8½ x 11, Paper. By Carl G. Deuber. April, 1956. Research Project PM-20, American Gas Association, 420 Lexington Ave., New York City. Per copy, $1.50.

Development of the instrument by Starkey and Wight to measure the oxidation-reduction potential of soil is described. Aim of the project is to develop a rugged and reliable instrument which will permit quick establishment of the redox potential of soils.

The improved probe has been submitted to the gas industry for field testing. The book describes the theory of and method of use of the probe.

Index to the Twentieth Semiannual Report to Congress, January 1956-June 1956. U. S. Atomic Energy Commission. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Per copy, 15¢.

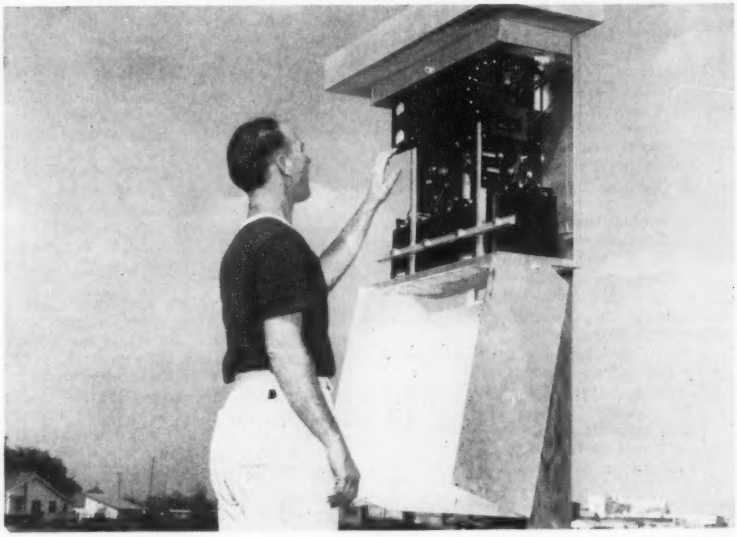
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National Petroleum Bibliography. 113 pages, 5½ x 8¼ inches, paper. Curtis Stevens, Editor. National Petroleum Bibliography, Box 3586, Amarillo, Texas. Per year, $35.

This is indicated to be an advance edition. The introduction says the edition is not intended to be representative of future editions, which are to be issued bi-monthly. The editor proposes to scan 400 periodicals and report titles and location of items significant in the petroleum field according to the Decimal System for Classifying Data Pertinent to the Petroleum Industry devised by C. L. Uren.

Nonperiodical publications of state and federal agencies, colleges and universities and other organizations will be listed also.

Sample copies are available on request.



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Nondestructive Testing Symposium Planned

A symposium on nondestructive test developed in the field of nuclear energy will be held April 16-18 at the Morrison Hotel, Chicago. Papers on reactor materials, fuel, sheath or cladding, control and moderator material; completed fuel assemblies and miscellaneous subjects will be given.

Sponsors are the American Institute of Chemical Engineers, American Nuclear Society, American Society for Testing Materials and Society for Non-Destructive Testing.

Titianium Is Plated With Chromium by New Process

Less galling under load and reduced oxidation at high temperatures are obtained with titanium chromium plated by a process developed at the National Bureau of Standards. The procedure involves forming a titanium fluoride film on the metal surface, electroplating with chromium and heat treating the plated specimen at 800 C.

The process was developed for the Springfield Armory by C. L. Stanley and A. Brenner of the bureau staff and reported in their paper "Adhesion of Electroplated Coatings to Titanium," in the Technical Proceedings of the American Electroplaters' Society 1956.

Radiation's Effect on Plastics Theme of Group

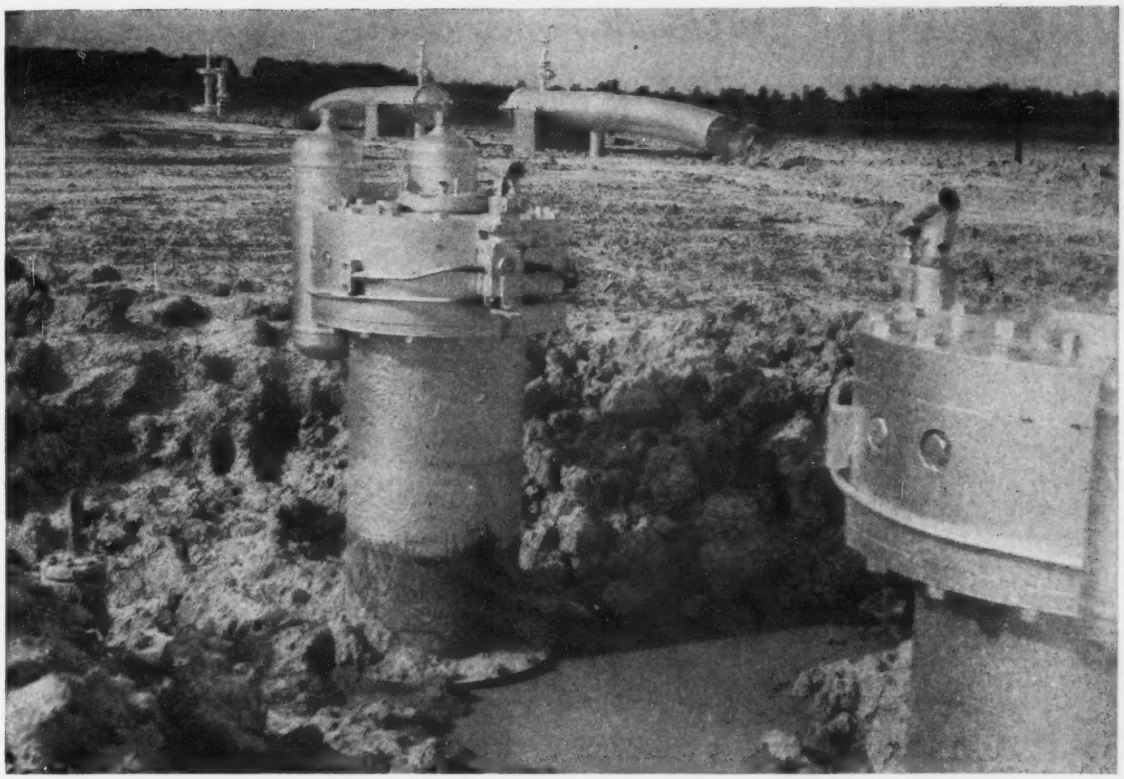
Effects of radiation on properties of plastics and electrical insulation will be explored by an American Society for Testing Materials sub-committee headed by D. S. Ballantine, Brookhaven National Laboratory. Prime objective of the committee will be to establish standard methods of irradiation and standard methods for determining effects of radiation on physical and chemical properties of plastics and electrical insulation.

Solar Engines Predicted

Solar engines will become increasingly important soon in arid areas of the world and economically feasible everywhere in the next 50 years believes Peter Courvoisier, research physicist of the solar observatorium at Davos, Switzerland. Depleted oil reserves will bring this change about, he believes. Atomic energy will not be able to fill power requirements when other fuels are exhausted, he said.

Short Course Scheduled

The second annual Appalachian Underground Corrosion Short Course will be given at West Virginia University, Morgantown, June 5-7. F. E. Costanzo, Manufacturers Light and Heat Co., is general committee chairman.



All Valves on American-Louisiana's 30" Line were COLD-COATED with ROSKOTE

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Jointly approved for use by American Louisiana Pipeline Company and their engineers, Ford, Bacon & Davis, Roskote was, in addition, used for some of the line patching where the original coating was imperfect or damaged. Two coats of Roskote were used, either by brush or pressure pump spray, and jeeped by the holiday detectors used on the line.

All three contractors, Houston Contracting Company, Brown & Root, Inc. and H. C. Price Company used Roskote on the project.

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For literature covering Roskote physical properties, application instructions and complete test data, write to Royston Laboratories or their nearest district office or distributor.

Standing in water-laden backfill, the Shafer-operated valves seen in the photograph above are given lasting, jeep-proven protection by below-ground coating of Roskote 612XM Pipe Mastic.

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Cathodic Protection Frequently Practical in Corrosion Control of Brewery Vessels*

Abstract

Galvanic corrosion among dissimilar metals used in breweries can be reduced by application of cathodic protection, frequently at considerable savings over other methods of protection. Proper coatings, usually supplemented by cathodic protection for submerged surfaces, help reduce equipment damage and downtime.

An example is given of successful substitution of cathodic protection for chromate treatment of pasteurizers that was causing accelerated corrosion. Pasteurizers are subject to fluctuating water levels and the system installed must take this into account.

Some examples of savings through engineered corrosion protection are given, including a saving of $10 per week per pasteurizer by cathodic protection over chromate inhibition reported to cost $12,000 a year. Repairs on one leak in an underground 30,000-gallon tank would cost $5000, not including lost production. Cathodic protection system for this tank would cost $1600 over 10 years and the tank would remain corrosion free. Cathodic protection permits using plain steel pasteurizers in place of costly stainless steel.

IN LOCATIONS where elevated temperatures are found, thermoplastic materials such as chlorinated rubber or vinyl resin paints are subject to early failure, particularly if the coating is also subjected to the action of detergents. Bottle-washing machines are an example of this type of operation. Caustic detergents are often used at 180 F. When the metal surface is properly prepared, suitable primer used, and proper application and curing techniques followed, paints of the epoxy resin type are very satisfactory for use where detergents are used at those temperatures.

Pasteurizer machinery is another type of equipment that presents a difficult problem in corrosion control, because the coatings must withstand sprays at 140 to 150 F for considerable periods of time. Zinc coatings or paints containing zinc are not satisfactory, as the equipment is operated at the temperature where the polarity of zinc to steel is reversed, accelerating the corrosion. Here again, proper preparation of the metal surface by shot blasting, etch priming, and the application of an epoxy resin film is probably particularly effective when coupled with a cathodic protection system to prevent corrosion at pinholes or breaks in the coating.

Other coatings and linings sometimes used are glass, vitreous materials and various waxes and varnishes. In all cases, the effectiveness of the coating depends upon maintenance of an unbroken film. The coating system used should be considered as a part of the original design of a structure and not as an afterthought.

Corrosion-Resistant Alloys

Corrosion-resistant alloys are used in the brewery primarily to prevent contamination of the beer. Pasteurizers are made from stainless steels to reduce maintenance costs caused by corrosion. Copper, Monel, and stainless steel are commonly used in the brew house, primarily to prevent contamination. For large brewing vats and wort kettles, copper is the favored metal due to ease of cleaning and fabrication. Monel is similar to copper in ease of fabrication and causes less contamination; however, the initial cost is higher. Higher fabrication costs and sensitivity to pitting if the metal is not properly heat treated have decreased the use of stainless steels for large vats and kettles in brew houses. Many stainless steel pasteurizers have been installed, however, and the endless belts in all pasteurizers are also made from stainless steel.

Cathodic Protection

As a specific example of cathodic protection being applied to underground structures, in one brewery a 50-volt 10-ampere rectifier operating on 220 volts AC furnishes current to 14 graphite anodes that are 3 inches in diameter by 60 inches long. This system provides cathodic protection to four underground tanks of 30,000-gallon capacity each. The anodes are evenly distributed around and between the tanks. The system has been in operation since January 11, 1955; no corrosion problems have occurred on the tanks to date.

Pasteurizers

Cathodic protection has been installed in plain carbon steel pasteurizers after failure of other methods of corrosion prevention. The usual installation is a rectifier with graphite anodes supported on steel brackets welded to the bottom of the tanks. The brackets are insulated from the anodes with a vinyl sleeve around the anode and vinyl tape on the upper part of the bracket.

(Continued on Page 136)

* An abridged version of an article by D. W. Hale, C. C. Horton and J. A. Michelson, The Hinchman Corp., Detroit, published in The Brewers Digest, August, 1956.

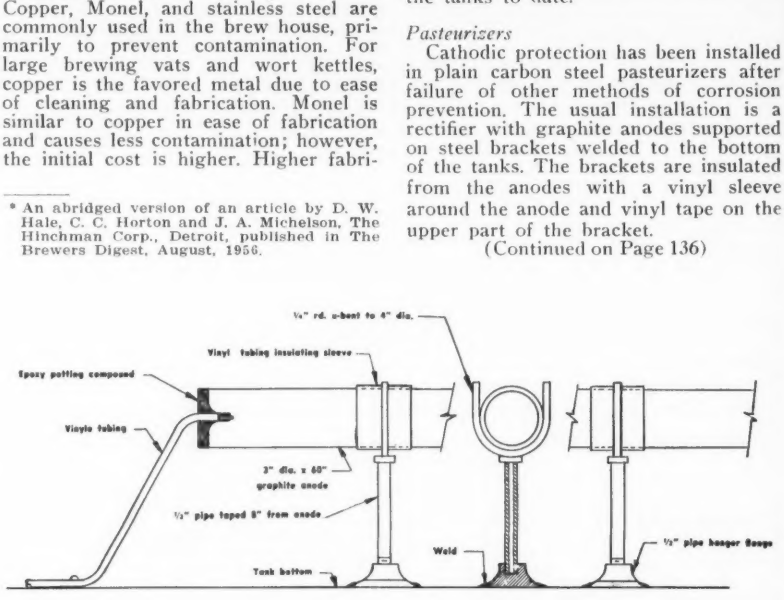
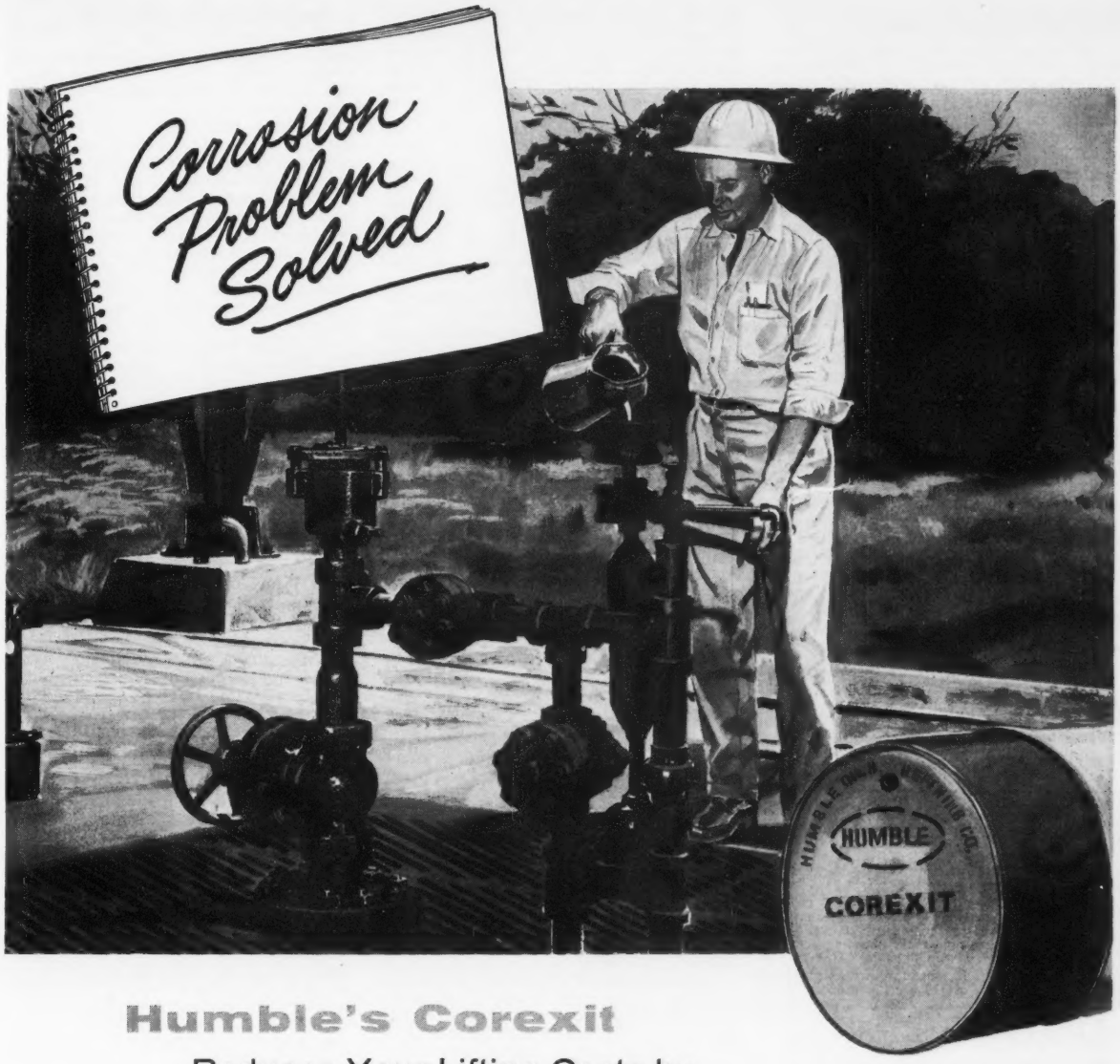


Figure 1—Typical installation of a graphite anode inside a pasteurizer tank.



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Cathodic Protection—

(Continued from Page 134)

The location of the anodes is selected so that a relatively uniform current density is applied when the system is turned on. Due to the shape of the tanks and the depth of the water, however, the anodes are closer to the bottom and side walls of the pasteurizer. As a result, these portions of the tanks initially obtain all the protection until a light brown iron oxide coating is deposited on the surface, increasing the contact resistance to passage of current in these areas.

The coating expands in area until the entire surface is covered. At this point, metal-to-water potential measurements indicate a comparatively large change in a negative direction along with a decrease in current drain to the particular anode circuit. The voltage required to drive the same amount of current through the anode is greater. At this time the system is adjusted to maintain protective potentials (—0.95 volt in the case of hot water contained in steel), as measured between the tank and the water, and the system will operate with minor maintenance for at least 10 years.

A diagram showing the method of mounting the anodes is shown in Figure 1.

Fermentation Tanks

Corrosion control in metal fermentation tanks presents a twofold problem in that mechanical failure causes shutdown and loss of output, whereas the control systems used must not affect the flavor of the finished product. The material contained in fermentation tanks is acidic in pH and contains considerable carbon dioxide. The electrical resistivity is of the order of 100 ohms per cubic centimeter.

Where dissimilar metals, such as copper coils and steel tank walls or stainless steel and mild steel, are in contact with the brew, the low resistivity of the electrolyte (brew) can promote galvanic action or electrolysis.

A system of cathodic protection used in conjunction with a good coating process offers many advantages in controlling the corrosion in fermentation tanks. The application of a coating to the tank walls will reduce the current requirements and operating costs of cathodic protection, and the cathodic protection system will prevent corrosion at pinholes or damaged spots in the paint coating.

An advantage of the application of cathodic protection to metallic fermentation tanks is the fact that the system may be installed on existing tanks, thereby prolonging the life of the tank indefinitely. Many installations are currently being fabricated of ceramics, which fact, of course, obviates the need for corrosion control.

Problems of Control

Inhibitors

Water systems in which chemical inhibitors are being used can present difficulties. The use of sodium dichromate in six pasteurizers at one brewery failed to prevent corrosion from taking place. Initial doses and daily additions of the chromate were made to maintain a concentration of 400 parts per million. Borax was added to control the pH between 8 and 9. Notwithstanding, pits as deep as 0.136-inch developed in the steel tanks in a two-year period. The cause of corrosion was determined to be inadequate concentration of chromate; in fact, corrosion pitting was increased by the inhibitor.

Cathodic Protection

The problems encountered in the application of cathodic protection to brewery equipment require careful planning and design. To be effective, cathodic protection must have a continuous electrolyte, which means that the anodes must be submerged at all times. To prevent early failure, the insulation of the electrical wiring and components in brewery equipment must be designed to operate under conditions of high temperature and high humidity. The selenium rectifiers commonly used as the source of the direct current for cathodic protection must be located where the ambient temperatures are below 120 F for efficient operation and long life. Changes in resistivity of the electrolyte must be considered and adequate allowance made for adjustment of the operating levels of the protection system. Variations in the electrolyte level will cause a variation in the wetted surface and in the current drawn by the cathodic protection system, which must be allowed for in the design. The various components in the system must be protected from mechanical damage to assure a continuous path of current to the structure under protection.

All these problems can be controlled by proper design of the original cathodic protection system and by proper maintenance procedures after the installation is made and adjusted.

Electrolyte Resistivity Changes

The water level in the tanks of a pasteurizer fluctuates due to fouling of the spray screens. This fouling is due to two causes, 1) the growth of molds and algae, which is encouraged by the high pH produced at the metal surface by the use of cathodic protection and the discontinuance of the use of dichromates as corrosion inhibitors, and 2) by labels and other paper matter that is carried over from the bottle washers. Such fouling prevents the water pumped to the top of the pasteurizer from getting back down to the tanks as rapidly as it is pumped out. As a result, the water level may become as low as three inches or less.

This low water level must be taken into account in the design of a cathodic protection system for the inside of a pasteurizer. The anodes are therefore mounted lower than necessary for submersion in a full tank, so that they will operate at low water conditions. The cathodic protection system must be able to accommodate extreme fluctuations in water level, which, in turn, will cause extreme fluctuations in current output by the rectifier.

Costs and Savings

Since the costs of the ingredients used in the making of beer are fairly well standardized among the various brewers, it follows that reduction of maintenance and equipment replacement costs will be reflected in the profit column of the annual statement. Control of corrosion is one way of reducing these fixed costs by extending the life of operating equipment and reducing downtime for repairs and replacement.

As an example, a brewery with metal fermentation tanks was investigated to determine the feasibility of installing cathodic protection systems for the tank interiors. The tanks had shown considerable pitting and corrosion of the mild steel side walls. As a result of this survey, it was estimated that all the tanks could be protected for 10 years at an estimated cost of approximately $50,000, including the cost of electrical power. The resultant annual cost of $5,000 is very small compared to the cost of replacing only a few of the tanks.

Installation of cathodic protection in the six pasteurizers of one brewery enabled this brewery to dispense with the use of chromate inhibitors to control corrosion and sodium carbonate to maintain the proper pH, at a saving of $10 per pasteurizer per week over and above electrical costs. Also, space formerly occupied by drums of these chemicals was made available for other uses. The success of these cathodic protection systems enabled the brewery to install new pasteurizers made from plain carbon steel rather than more expensive pasteurizers made from stainless steels.

The chromate inhibitor treatment for the pasteurizers, which actually intensified the corrosion problem, was reported to cost $12,000 per year. Maintenance of a concentration adequate for corrosion control was estimated to cost $14,500 per year. These same pasteurizers were placed under cathodic protection for an approximate original outlay of $17,100, with an approximate annual cost of $500 for maintenance and power.

The cost of repairs on underground structures due to corrosion from the soil are large, in some cases exceeding

(Continued on Page 137)

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members and Companies seeking employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Advertisements to other specifications will be charged for at $10 a column inch.

Positions Available

Corrosion Engineer for Synthetic Textile Plant, Carolinas area, familiar with theory and application of chemical plant corrosion control and inspection techniques. Excellent opportunity, salary and fringe benefit program. Write, stating experience, education and salary desired to L. Amato, P. O. Box 1001, Rock Hill, S. C.

Positions Wanted

Corrosion Engineer—Supervisory experience in metal inspection control and development laboratory and corrosion testing and mitigation. East or Midwest. CORROSION, Box 57-2.

Administrative Corrosion Engineer—Good progress record covering laboratory evaluation, technical reporting, sales-service, manager of phosphate coating manufacturing plant. Presently supervisor surface treatment corrosion lab covering missile systems. Resumé upon request. CORROSION, Box 57-1.

Essen Program Scheduled On Passivation, Layers

Passivation and the Formation of Covering Layers in the Atmosphere and in Water is the subject of a scheduled May, 1957 meeting to be held in Essen, Germany. The meeting is under auspices of Deutsche Gesellshaft fur Metallkunde, the Verein Deutsche Eisenhuttenleute and Verein Deutscher Ingenieure.

An autumn meeting will be held in Zurich of the European Federation of Corrosion. A joint meeting of the Swiss Societies: Schweiz. Elektrotechnischer Verein, Schweiz. Ingenieur und Architekten Verein, Schweizer Verein von Gas und Wasserfachmannern, Schweizer Verband fur die Materialprufung der Technik is scheduled.

Corrosion Course Begun At University of Brussels

A 20-lesson course titled "Researches on Electrochemical Corrosion" opened November 10 at University of Brussels in collaboration with Centre Belge d'etude de la Corrosion. Also included are 40 hours of laboratory work.

Subjects to be covered are chemical and electrochemical reactions, chemical equilibrium, electrochemical equilibrium, electrochemical movement, corrosion and protection of iron and steel, examples of corrosion protection.

Russian Atomic Research Center Opened at Dubna

A $125 millions atomic research center was opened in September at Dubna, 95 miles from Moscow, Russia. One of the pieces of equipment is a 10,000 mev synchrotron. The University of California has a 6000 mev bevatron. (Isotope Newsletter, Oct. 56)

Aluminum Extrusions Clad

Impact extrusions clad with a thin surface layer of metal providing cathodic protection can be produced now, according to Aluminum Company of America. The development makes possible the use of impact extrusions for service heretofore impractical because of lack of corrosion resistance. The Alclad process is employed.

Plastics Engineers Society Schedules Three Meetings

Society of Plastics Engineers, Inc. has scheduled the following 1957 meetings:

Jan. 16-18—Thirteenth National Technical Conference, St. Louis.

April 3—Regional Technical Conference "Plastics for Building," New York.

June 14—Regional Technical Conference "Plastics for Electronics," Massachusetts Institute of Technology.

Cathodic Protection—

(Continued from Page 136)

the original cost of installation. It is estimated that in 10 years the repair of one leak per year on a 30,000-gallon underground tank would amount to $5,000 alone, not counting losses due to inoperation of the tank. A cathodic protection system for this same tank would cost approximately $1600 over a 10-year period. If the system were properly designed, installed, and maintained, the tank would remain corrosion free.

Conclusions

Cathodic protection is recommended for pasteurizers to prevent corrosion of the tanks. This makes it possible to use plain carbon steel in the construction of pasteurizers, thereby reducing their cost. The total cost including cathodic protection is less than that of installing a pasteurizer made from stainless steel. Elsewhere, where cathodic protection is not feasible, appropriate coatings and corrosion-resistant alloys shoud be used.

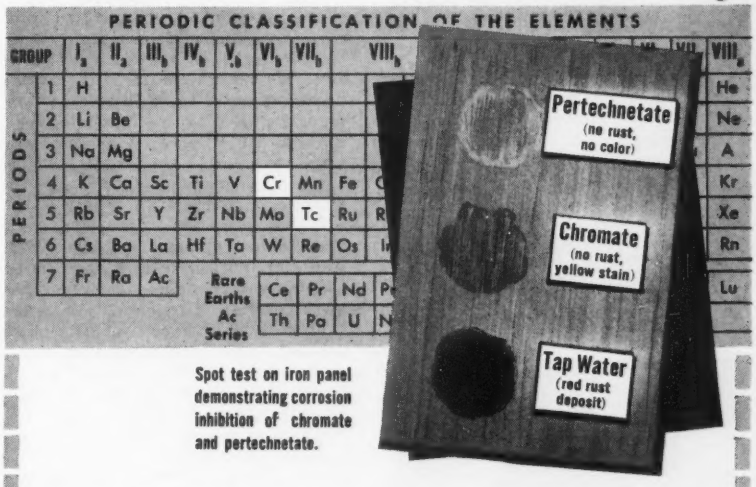
Underground fuel tanks and pipes should have cathodic protection. The area around the boiler and power plant usually is paved, and the tanks and piping are installed under concrete, making it costly to repair or remove them. Installation of a protective system at the time the tanks are installed will save money and work time by preventing failures, which often occur in as short a period as five years.

Operating equipment in breweries subject to corrosion that can be protected by proper mitigative methods, or the selection of proper construction materials include hot water tanks, wort cookers, wort coolers, fermentation tanks, beer storage tanks, and pasteurizers.

The life of building structural members, machinery exteriors, electrical power distribution systems, control equipment, and other physical plant structures can be greatly extended by early and regular consideration of the corrosion problems involved.

...what is your

best corrosion inhibitor ?



Spot test on iron panel demonstrating corrosion inhibition of chromate and pertechnetate.

Recent research* with a very rare man-made metallic element called technetium has shed new light on the mechanism of corrosion inhibition.

Experiments have demonstrated that even in concentrations as low as 5 ppm and at temperatures of 450° F., pertechnetates completely inhibit iron oxidation. But technetium is a synthetic element obtained by bombarding molybdenum with deuterons, or in the fission of uranium as a fission product. As a result it is extremely scarce and prohibitively expensive.

Fortunately, chromates have an ionic structure very similar to that of the pertechnetates, permitting dependable and efficient corrosion control at a tiny fraction of the cost of technetium compounds.

Mutual Chromium Chemicals have been widely used for corrosion control for many years, during which time we have accumulated much useful experience. May we help you with your corrosion control program?

*Sci. Am. 194, 35-39 (May 1956)

Sodium Chromate • Chromic Acid • Sodium Bichromate • Potassium Bichromate • Potassium Chromate

MUTUAL CHEMICAL DIVISION

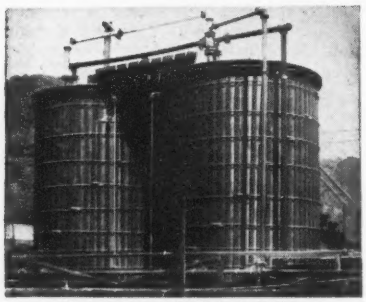
MUTUAL — ALLIED CHEMICAL & DYE CORPORATION

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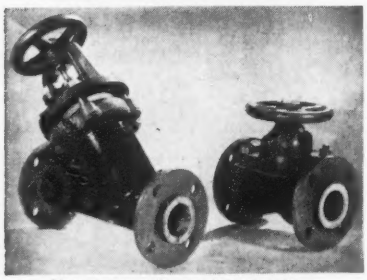
HAVEG® News

Wherever CORROSION RESISTANCE is a Factor

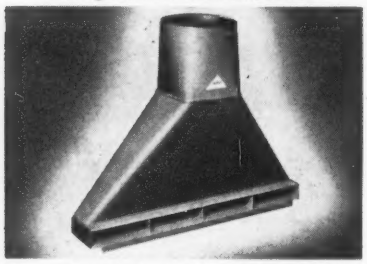
IF CORROSION IS THE PROBLEM HAVEG PLASTICS ARE THE ANSWER!



Haveg storage tank installation



Haveg corrosion resistant valves



Large Haveg polyester glass self-supporting fume hood



Haveg light weight polyester glass tanks

Rugged strength and durability . . . exceptional resistance to corrosion . . . longer, trouble-free service at process temperatures as high as 350°F.—you get them all at bonus savings in installation time, material, and maintenance costs with Haveg plastic equipment.

PROCESS PIPE, TANKS, TOWERS, FUME REMOVAL SYSTEMS, DISTILLATION COLUMNS, FILTER PRESS PLATES—wherever industrial equipment is required to handle corrosive materials or atmospheres—Haveg corrosion resistant plastics have solved the problem at leading process plants. In addition to equipment a wide selection of Haveg resin cements offer required chemical resistant properties for extensive use as mortar in chemical brick and tile flooring, equipment lining, etc.

Haveg phenolic, furan, polyvinyl and polyester resins are selectively formulated to provide maximum resistance to the corrosive chemicals used in your particular operations . . . acids, hypochlorites, chlorinated solvents, salts, alkalies, hydrocarbons, and a variety of oxidizing agents. Excellent machining and molding characteristics permit economical fabrication of a wide range of intricate shapes and sizes to meet exacting specifications. Write for illustrated Bulletin C-13.

HAVEG DESIGNS, ENGINEERS, BUILDS YOUR PROCESS EQUIPMENT

Skilled Haveg corrosion engineers, experienced in designing and engineering corrosion resistant equipment for diverse industrial applications, will develop equipment to meet your process needs . . . to assure you full advantage of Haveg's low cost methods. Designed and fabricated to your specific requirements, each Haveg installation is guaranteed to give top process performance! Details of this unusual service are available at no obligation from a qualified Haveg sales representative. H-602

HAVEG PLASTICS OF TOMORROW SOLVE YOUR CORROSION PROBLEMS TODAY

HAVEG INDUSTRIES, INC. 930 Greenbank Road, Wilmington 8, Delaware Factory: Marshallton, Del. phone WYman 8-2271

Atlanta Exchange 3821 | Chicago (Wheaton) Wheaton 8-3225 | Cleveland WAshington 1-8700 | Detroit (Livonia) KEnwood 1-1785 | Houston JAckson 2-6840 | Los Angeles MUtual 1105 | New York (Westfield, N.J.) WEstfield 2-7383 | Seattle Main 9006 | Denver BElmont 7-0433

Los Angeles Smog Control May Cost $40 Millions

Expenditure of $40 millions to solve the Los Angeles smog problem in less than 10 years is forecast by Lauren B. Hitchcock, president of the Air Pollution Foundation. The foundation expects to devote its principal energies toward control of pollution by internal combustion engine exhaust.

Spectrographic Samples of Zinc Base Alloys Available

Spectrographic standard samples of six new zinc-base alloys are available now from the National Bureau of Standards. The standards are designed for calibrating and checking spectrographic methods in the analysis of two important zinc-base die casting alloys (ASTM designations AG40A and AC41A).

AWS Meeting to Consider Titanium, Zirconium

Welding of titanium and zirconium, brazing stainless steels and high temperature alloys, new techniques in precision welding control, filler metals for welding high-strength steels, zinc soldering of aluminum and other subjects will be discussed April 8-12 during the National Spring Meeting of the American Welding Society in Philadelphia.

Paint Research Institute

Broad research and the fostering of technical education for the benefit of the entire decorative and protective coatings industry will be the aim of a Paint Research Institute to be established by The Federation of Paint and Varnish Production Clubs.

AIChE Meetings Scheduled

Meetings of the American Institute of Chemical Engineers scheduled during 1957 are as follows:

March 3-6—White Sulphur Springs, Va.

June 9-12—Seattle, Washington.

Sept. 15-18—Baltimore, Md.

Dec. 8-11—Chicago, Ill. Annual meeting.

Columbia-Southern Quarterly Is Published

A full-color offset quarterly published by the Columbia-Southern Chemical Corp., One Gateway Center, Pittsburgh includes, in Vol. 1, No. 2, the fall 1956 issue, stories concerning the dry-cleaning industry, the company's Barberton, Ohio trichlorethylene plant, paper making and its Natrium, West Virginia chlorine plant.

ASM Abstracting Shifted

The ASM Review of Metal Literature, abstracting service of the American Society for Metals has been transferred to Western Reserve University, Cleveland.

•

Topical indexing of the 629 articles published in CORROSION's Technical Section 1945-54 is provided in the 10-Year Index to CORROSION.

Equipment Services NEW PRODUCTS Materials Literature

Cement-Lined pipe in use 20 years has been reinstalled in a water flood system by Forest Oil Corporation near Nowata, Okla. The pipe has been used to transport water containing salt, hydrogen sulfide and other corrosives.

•

Reinforced Plastics, which scored a sales gain of 30 percent in 1956 over 1955 will have an equal growth in 1957 according to Reinforced Plastics Division, Society of the Plastics Industry, Inc.

•

Zippertubing, a polyvinyl chloride zipper enclosed tubing is designed as a protective covering for groups of electrical wires by W. A. Plummer Mfg. Co., 752 San Pedro St., Los Angeles, Cal. Inside diameters are from ½ to 4½ inches in increments of ⅛-inch. They are available in lengths from 20 to 1000 feet.

•

U. S. Industrial Chemical Co., Division of National Distillers Products Corp., 99 Park Ave., New York 16, N. Y. has taken an exclusive option on a process for separating hafnium from zirconium developed by the Commonwealth Scientific and Industrial Research Organization of Australia. Hafnium is an undesirable element when zirconium is used in atomic reactors.

•

Dow Corning Silicone Products are described in a 1957 guide available from the company's Midland, Mich. offices.

for
HANDWRAPPING
"hot lines" and "holidays"
GLASFAB©
EASY TO APPLY — RELIABLE
HIGH TENSILE STRENGTH
A wholly inorganic, loom woven glass fabric — ideal for handwrapping pipe joints and extensions — Glasfab is non-capillary and adds year to the life of coal-tar, asphalt bitumen, or plastic coatings.
MIDWESTERN
PIPE LINE PRODUCTS CO.
Box 1886 Tulsa, Oklahoma

Copon will be manufactured and distributed by McDougall-Butler Co., Buffalo, N. Y. Martin E. Sleicher is technical director.

•

HP Controlled Capacity Pumps for pressures to 35,000 psi manufactured by Philadelphia Pump & Machinery Co., 13500 Philmont Ave., Philadelphia, Pa. are described in Catalog HP-1254 available from the company. HP pumps are offered in 298 models in three sizes and 2-inch, 3-inch and 4-inch strokes.

•

Teflon applied as a water suspensoid by air or electrostatic spray to ordnance stored by the U. S. Marine Corps protected it against long term storage despite total lack of care, according to the Office of Technical Services. Coated equipment was ready for use as it was removed from packing. Teflon afforded lubrication for small arms under all circumstances for an almost indefinite period.

•

Chemplas 15, a furan resin and inert ceramic is used for the production of pipe and fittings, towers of all kinds and containers. The material and its uses are described in a folder available from General Ceramics Corp., Keasbey, N. J.

•

Remainder of the American Louisiana Pipe Lines Company's 1200-mile pipe line will be protected cathodically against corrosion by Cathodic Protection Service, Houston. CPS already had protected parts of the system, including sections in highly corrosive soils and structures at compressor stations before a decision was reached on the remainder.

•

Unichrome dip coatings, designed for low cost application as finishes for zinc and cadmium plated materials have been developed by Metal and Thermit Corp., Rahway, N. J. The four new compounds make possible dip coating for services ranging from outdoor exposure to shelf storage.

•

Cathodic Protection Test Leads are included in a built-in junction box incorporated in a pipe line vent marker available from Tod Pazdral Pipe Line Specialties, 2525 S. Boulevard, Houston. The L&M markers are cast in heavy malleable aluminum alloy with a sign panel designed and painted in using company's colors.

•

Nickel-Producing operations in Northern Manitoba approved by the Province of Manitoba and International Nickel Co. of Canada, Ltd. will cost $175 millions. The project, which includes government construction of a $32 million hydroelectric power plant at Grand Rapid on the Nelson River, is expected to bring Inco's nickel producing capacity to 385 million pounds, or about 50 percent more than the firm's 1955 production. A portion of the added production will be available for purchase by the United States government. The location is 400 miles north of Winnipeg and 950 miles from Sudbury. The townsite at Thompson will have 8000 population.

Coreco, Inc., P. O. Box 19177, Houston 24, Texas will supply on request its data file on cathodic protection systems consisting of articles appearing in the trade press authored by Wayne Johnson.

•

Dimetcote No. 3, the 100 percent zinc coating said by the manufacturers, Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal. to give protection equivalent to galvanizing for periods up to 15 years is described in a bulletin available from the company. The coating contains no organic materials but can be applied with conventional spray equipment.

•

Allied Porcenell, Inc., 851 S. Market St., Waukegan, Ill. is marketing its silicate modified coating Profilm through a nationwide network of distributors. The coating, developed by a company owned jointly by Poor & Co., Chicago and Youngstown Sheet & Tube Co., Youngstown, Ohio, is available in colors and comes in white, black, clear and metallics in both baking and air dried grades. Manufacturers claim the coating can be applied to virtually any material, including masonry, wood and asbestos.

•

Ceramic Coatings are being applied to muffler surfaces of large truck and bus manufacturing companies with the result that mufflers last over 300,000 miles in some instances. Toledo Porcelain Enamel Products Co., a division of The Bettinger Corp., Waltham, Mass. says the coating guards the exhaust systems against ice melting salt, heat oxidation to 1400 F, lead bromide gases and thermal shock from 1400 F to ambient temperatures.

•

Sifco Insert Flanges, a bi-metal product of stainless or other corrosion resistant metal and carbon steel, are designed so that when assembled and placed in use only the insert comes in contact with the corrosives. Manufactured by Stainless Insert Flange Co., 6526 Upland St., Philadelphia they are available in Types 304 and 316 stainless and in sizes from ½-inch ips to 6-inch ips for use with Schedules 5, 10 and 40 pipe. Other sizes are available.

•

Economy Paint Spraying outfits are available from The DeVilbiss Company, Toledo, Ohio. The P-QGA gun is designed for general spray work and has a quart metal cup and is a pressure feed model. The P-CGA spray gun is a combination model for both suction and pressure feed. The NCA compressor produces a maximum of 40 psi and has a direct drive.

•

Chevenard Creep and Relaxation Tester, one of the two on the North American Continent has been received by the Shell Development Company's Materials Engineering and Corrosion Laboratory at Emeryville, Cal. The instrument permits measuring change of strain with respect to time at a constant load and the decrease in load with respect to time at constant strain.

(Continued on Page 140)

NEW PRODUCTS

(Continued from Page 139)

Carbomastic is the name of a new series of protective coatings available from the Carboline Co., 331 Thornton Ave., St. Louis 19, Mo. The coatings, epoxy-tar compounds with solids content ranging from 85 to 90 percent and applied at thicknesses up to 10 mils per coat, consist of a five member series. Each has specific applications. Excellent resistance to water, humidity, brine, refinery products, ultra violet light, hydrogen-sulfide gases and other salts, acids and alkalis is claimed. General recommendations call for two coats, approximately 20 mils, at cost of less than 1¢ per mil foot.

•

Alumina, substantially equal to that from bauxite is being extracted from clays in the area of Moscow, Idaho by The Anaconda Company. The problem of extracting alumina was solved after two years of laboratory and test plant work. Attempts have been made without success over a period of 25 years to extract alumina from domestic clays. Vast reserves of clay deposits in the Moscow vicinity have been put under option by the company in anticipation that a 50-ton-a-day pilot plant now being designed will prove the commercial feasibility of the laboratory work.

•

Kennametal Grade K-6 nibs and seats were used to replace steel parts in bleed-off valves controlling the flow of chocolate liquor at high pressure in food processing equipment made by Fred S. Carver, Summit, N. J. The new parts saved an estimated $388 in parts alone in 2½ years.

•

Immunol, a non-alkaline, non-acid detergent and rust preventive marketed by Harry Miller Corp., 4th and Bristol St., Philadelphia is described in a 12-page booklet available from the company. Manufacturers says it eliminates problems associated with dermatitis and can be used by wiping, dipping or spraying.

Heavy Scale can be stripped in a few minutes at 145 F in non-aqueous solutions of Monitor A, such as 60-70 percent in formamide. Monitor A, an organic high molecular weight polyhydroxy compound is completely miscible in water, lower alcohols, polar organic solvents and aqueous solutions of water-miscible solvents. It is solvent in strong concentrations of acids, alkalis and electrolytes. It is manufactured by Globe Compound Co., Inc., Waterbury-Bristol Road, Waterbury 12, Conn.

•

Met-All, a paste polish developed in West Germany and imported by John Anton Co., 15 Bridge St., New York 4, N. Y. is reported to restore tarnished metals to original luster and protect the resultant finish for many months. The material will polish aluminum to a chromelike finish and protect it against pitting, the importer claims.

•

Condensed Reference File, 1957, a 16-page booklet available from Bakelite Company, a Division of Union Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y. describes the principal kinds, characteristics and fabrication techniques of plastic materials made by the firm.

•

Lignin Sulfonates, which have ability to disperse particles in water and hold them in suspension are being marketed by Crown Zellerbach Corp., 343 Sansome St., San Francisco, Cal. Orzan-P, a spray-dried powder, may be precipitated even from dilute solutions by addition of alum. It is recommended for use as a binder for fibers, retention of fines, an emulsifier, an emulsion stabilizer, a flocculant and a dispersant. About five types of the material presently are being marketed.

•

Resin Research Laboratories, Inc. has broken ground for a new Resin Research Center at 400 Adams St., Newark, N. J.

•

Water Analysis, Bulletin 11 of Solvay Process Division, Allied Chemical & Dye Corp., 61 Broadway, New York 6, N. Y. has been issued in a revised, 100-page edition. Copies may be obtained without cost on request.

Bahrain Petroleum Co., Ltd. is installing a plant to produce 86,000 gallons of fresh water a day by electrical purification of salt water. The plant was developed by Ionics, Inc., 152 Sixth St., Cambridge 42, Mass.

•

Carpenter Steel Company has opened a mill-branch warehouse at Houston under Charles E. Miller, branch manager.

•

United Chromium of Canada, Ltd., an office warehouse and manufacturing facility of Metal & Thermit Corp. has been completed on Factory St. in the Highbury area of Etobicoke Township in northwestern Toronto.

•

Mak-A-Key zinc plated key stock marketed by the De Van Johnson Co., Aurora, Ill. eliminates need for rust preventives.

•

Sylvania Electric Products, Inc. has taken an option on a 150-acre site in the town of Andover, Mass. as the location for a proposed multimillion dollar atomic center. Sylvania-Corning Nuclear Corp. will be formed to operate the project.

•

Columbia No. 7, a lining developed by Columbia-Southern Chemical Corp. was applied over a special chlorinated rubber primer to the insides of five 60-foot concrete silos at Pittsburgh Plate Glass Company's Cumberland, Md. plant. Tank Lining Corp., Pittsburgh, says it is believed to be the first time a plastic coating has been used to line silos of this type for storage of soda ash, sand, limestone and dolomite.

•

Vinyl-Coated Dynel is being fabricated into trim, wainscoting and other interior parts for installation in aircraft.

•

Quelcor of Cincinnati has been organized as a subsidiary of Quelcor, Inc., Chester, Pa. extending the firm's operations into an area where customer demand has been increasing. John Kozacik, with long experience in the chemical industry, is president of the new firm which is located at 1050 Hulbert St., Cincinnati 14, Ohio.

•

Resistoflex Corp., Roseland, N. J. has issued a loose-leaf catalog containing technical data sheets, specifications and prices of its line of corrosion resistant flexible hose and fittings.

Nuclear Engineering Congress Is Scheduled

The Second Nuclear Engineering and Science Congress of the Engineers Joint Council will be held March 11-15, 1957 at Convention Hall, Philadelphia. Concurrently there will be held the Fifth Atomic Energy for Industry Conference conducted by the National Industrial Conference Board, the International Atomic Exposition and the Fifth Hot Laboratories and Equipment Conference.

Metal Physics Section

A Metal Physics Section organized by the National Bureau of Standards is headed by Lawrence M. Kushner.

•

The 10-Year Index to CORROSION lists 1056 authors.

APEX for cathodic protection

MAGNESIUM ANODES



Corrosion control for under-ground and under-water pipelines and other metal structures regardless of all other methods used.

Anode folders or technical consultation with our engineers available upon request.

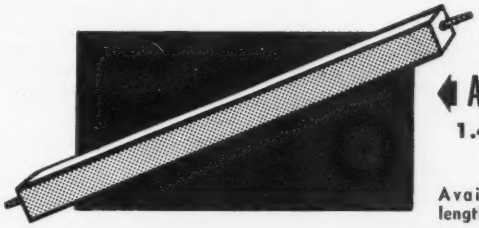
APEX Anodes are available in 17 lb. and 32 lb. bare anode with or without wire, or complete packaged anode with wire and back-fill ready for installation.

APEX SMELTING COMPANY

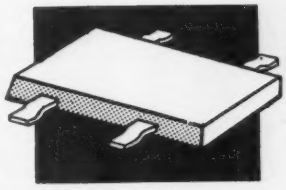
ZINC ANODES

Manufactured by AMERICAN ZINC, LEAD and SMELTING CO.

HERE ARE TWO OF THE NUMEROUS SHAPES OF ZINC ANODES OF SPECIAL HIGH GRADE (99.99% ZINC) . . .



AZCO 2-18
1.4" x 1.4" x 36"
Available in any length up to 60".



AZCO 8-24
1.25" x 6" x 12"
Ship hull anode



Recent installation of a 60 lb. AZCO 4-60 Zinc Anodes, one of 365 on an 8" Gulf Coast oil pipe line, using CPS bentonite-gypsum backfill. Line protected was 4½ miles in length, only 1 mile of which was well coated. AZCO 4-60 (2" x 2" x 60" long) anodes were installed every 50 feet, offset 3 to 5 feet from pipe line. Anode output averaged 400 milliamperes; soil resistivity averaged 400 ohm-cm.

FIRST LINE MATERIALS INCLUDE:

Duriron Anodes
Dow Magnesium Anodes
American Zinc Anodes
CPS Graphite Anodes
Good-All Rectifiers
Scotchrap Tape Coatings
Betzel Tapesters
Maloney Insulating Materials
Erico Cadweld Welding Materials
Fisher M-Scope Pipe and Cable Locators
Detectron Pipe Locators
Wahlquist Pipe Locators
CPS Graphite Anode Backfills
Homco and Barada and Page Backfills
Agra and CPS Meters
Associated Research Resistivity Meters
Rubicon Potentiometers
Pearson Holiday Detectors
Holloway Shunts
Rome Direct-Burial Cable
Ditch-Witch Trenchers

cathodic protection service

Everything in the cathodic protection field . . . from an insulating washer to a turnkey contract installation.

OFFICES LOCATED IN HOUSTON
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JAckson 2-5171

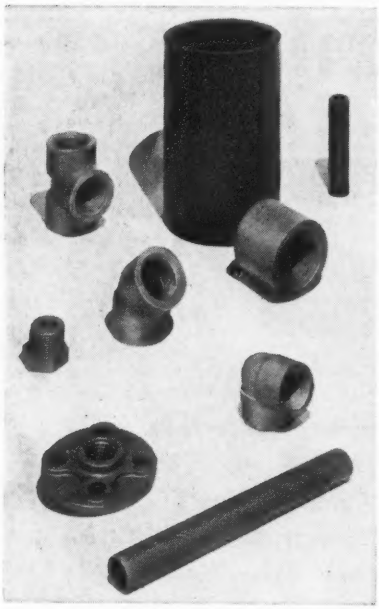
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310 Thompson Building
Tulsa 3, Okla.
CHerry 2-9857

NEW ORLEANS
1627 Felicity
CAnal 7316

CORPUS CHRISTI
1522 So. Staples
TUlip 3-7264

DENVER
(Golden) P. O. Box 291
CRestview 9-2215

LUZERNE
PVC
PIPE & FITTINGS
Will
Help Solve Your
Corrosion Problems!



Having trouble with corrosion or internal build-up of slime and scale in your piping? The smooth inside surface of LUZERNE rigid, unplasticized Polyvinyl Chloride Pipe and Fittings means less of this difficulty; and because it's non-metallic, electrolytic action is eliminated, too.

LUZERNE PVC Pipe and Fittings are light in weight, easy to install with either screwed fittings or welding socket fittings, and economical. Immediate delivery. Sizes ½" to 6". (Large sizes on request.)

SEND FOR BULLETIN PF-1100

LUZERNE offers an improved and expanded line of HARD RUBBER VALVES for Chemical Applications . . . Flanged Valves . . . Threaded Screw Straight Way Valves . . . Screw Stem Angle Valves . . . Globe Valves . . . all with improved Du Pont Teflon packing.

Custom Molding

The LUZERNE RUBBER CO.

300 Muirhead Avenue Trenton, N. J.

Sales Representatives

ALBERT J. COX CO.
Chicago, Ill.

R. C. FOLTZ CO.
Houston, Texas

I. A. RUBBER & ASBESTOS WORKS
Los Angeles, Calif.

MEN in the NEWS

E. J. Ripling has been appointed laboratory director of mechanical metallurgy of the Continental Can Company's new Central Research and Engineering Division, Chicago. He formerly was assistant professor of metallurgy at Case Institute of Technology.

•

J. S. Gillespie, acting manager of the industrial diamond project for General Electric's Metallurgical Products Department, Detroit has been named manager of engineer.

•

K. W. Thompson, president of K. W. Thompson Tool Co., New Hyde Park, L. I., New York has been elected president of the Investment Casting Institute.

•

Marvin W. Formo and **Alexander Olotka** have been promoted to the position of assistant research director and Louis I. Hansen, has been promoted from research supervisor to senior research associate of Archer-Daniels-Midland Co., Minneapolis.

•

Theodore Weaver, manager of the Process Development Department of the Fluor Corp., Ltd., Los Angeles has been named winner of the 1956 Junior Award of the American Institute of Chemical Engineers.

•

Wesley A. Robinson has begun postdoctoral research in solid state physics at the National Bureau of Standards. He plans to measure pure quadruple resonance in solids by observing the absorption of high frequency sound at the resonance frequency.

•

Joseph W. Tomecko, assistant general manager of the Paints Division of Canadian Industries, Ltd., Montreal has been named president-elect of the Federation of Paint and Varnish Production Clubs.

•

Robert Roy White, professor of chemical engineering at the University of Michigan has been selected as the winner of the 1956 Professional Progress Award in Chemical Engineering of the American Institute of Chemical Engineers.

•

Clinton R. Hilliker has been named operating manager and a director of Sperry Western, Inc.

•

Ray M. Wainwright has been appointed director of engineering of Good-All Electric Manufacturing Co., Ogallala, Nebraska.

•

James W. Pollard, Jr. has been appointed chief engineer of The Glidden Company. He will have full responsibility for all design, engineering and construction work throughout the company.

•

Philip J. Clough has been named director of the Metallurgical Research Department of the National Research Corporation, Cambridge 42, Mass. He is an NACE member.

•

Walter Bryant has been named Perrault Equipment Company's Southwest District field representative. A Navy veteran, Bryant formerly was with Stanolind Exploration Co. and Arey Construction Co., Pampa, Texas.

•

John A. Olmsted III of Petaluma, Cal. and **Terry E. Sharp** of LaCrosse, Wis were winners respectively of the sophomore and senior 1956-57 Warner Prizes in Chemistry. The prizes were established by J. C. Warner, president of Carnegie Institute of Technology and former head of its Department of Chemistry.

•

Charles E. Bulloch has been named Director of Products Development for the A. O. Smith Corp., Box 584, Milwaukee 1, Wis. a newly created position

•

Lew M. Jacobsen has been appointed national sales manager of the Fuel Oil Conditioning Division, Wright Chemical Corp., 627 West Lake St., Chicago 6, Ill.

•

A. H. Humble is a new staff member of Corrosion Services, Inc., P. O. Box 7343, Tulsa. Associated with the Corrosion Department of Gulf Refining Corp., Tulsa since 1947, he has worked on corrosion problems involving storage tanks, pumping stations and pipe lines.

•

Donald Garrett has been named assistant manager of the Trona research department of American Potash & Chemical Corp. and **Stanley Cohen** has been appointed head of the new products section.

•

John P. Nielsen, New York University, was the guest of the Soviet Academy of Sciences during the month of November lecturing at the Institute of Metallurgy in Moscow and attending a conference on atomic energy there.

•

Harold C. Templeton will direct metallurgical research in corrosion resistant alloys and supervise the synthesis and composition of alloys used in valves manufactured by Alloy Steel Products Co., Inc. He has been named chief metallurgist and formerly was chief metallurgist for the Lebanon Steel Foundry. Among other organizations he is a member of NACE.

•

Martin Aaron, materials engineer has been appointed assistant to the president of Sam Tour & Co., Inc., and its affiliate American Standards Testing Bureau, Inc. He will assume general management and customer relations responsibilities involved in the corrosion testing of zirconium and special alloys for use in reactors.

•

Donald H. Tilson is new manager of Aluminum Company of America's Northwest operations succeeding C. S. Theyer, retired after more than 43 years with Alcoa.

•

William F. Ryan, Stone & Webster Engineering Corp. has been installed as president of the American Society of Mechanical Engineers.

•

James P. Haight has become vice-president in charge of engineering and purchasing for Aluminum Company of America, succeeding Thomas D. Jolly, retired after 42 years with the company.

•

J. J. Haney, 58, Grand Rapids, Mich. sales representative of Metal & Thermit Corp. died November 24 while on a hunting trip. An employee of the company since 1944, he was active in the American Electroplaters Society.

CORROSION ABSTRACTS

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2. TESTING

2.3 Laboratory Methods and Tests

2.3.4, 2.3.9, 3.2.3, 6.2.5

Chemical Analysis of Thin Films by X-Ray Emission Spectrography. T. N. RHODIN. *Anal. Chem.*, **27**, No. 12, 1857-1861 (1955) Dec.

X-ray emission spectrography has been applied to the quantitative analysis of thin (approximately 100 Å) evaporated films of iron, nickel, chromium and Types 304, 316 and 347 stainless steels deposited on Mylar polyester backing. Oxide films associated with passivity and atmospheric oxidation, isolated from Types 304, 316 and 347 stainless steels were also studied. The corresponding surface densities of the sample films varied from 1 to 100 x 10^{-6} g/cm.^{2} Analytical sensitivities for the three metals corresponding to a counting rate of 60 cpm ± 5% are 0.037, 0.061 and 0.175 x 10^{-6} g/cm^2 for nickel, iron and chromium respectively. Comparison of the metallic compositional data obtained by x-ray methods for metal and oxide films 300 Å in thickness or less to those obtained independently by microcolorimetric methods indicates excellent agreement. (auth). —NSA. 11513

2.3.7, 5.4.7

To Correct Paint Film Measurement Error. F. STEINHEBEL. *Ind. Finishing*, **32**, No. 1, 126-127 (1955).

Steel parts when sprayed by electrostatic methods become slightly magnetized so that the readings for magnetic-type film thickness gauges become unreliable. It is suggested that in production work the applied film thickness can be measured by attaching a strip of steel shim stock to the post before spraying and then measuring the thickness of shim and paint with a micrometer.—RPI. 11561

2.3.7, 3.5.3

Corrosion. M. G. FONTANA. *Ind and Eng. Chem.*, **48**, No. 1, 115A-116A (1956) January.

Equipment and procedures for testing erosion-corrosion. Included are glass-lined and all-metal tank systems where specimens are rotated or suspended, loop tests where actual use conditions are duplicated and disk specimens on rotating spindle.—INCO. 11614

2.3.9

Applications of Radioactive Methods to the Study of Surface States and Surface Reactions of Metals. M. HAISSINSKY. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 98-112; disc., 112.

A review of surface phenomena of electrochemical interest. For an energetically homogeneous surface, electrolytic deposition should not take place before a critical potential, at or above which nearly all the depositing ions should be discharged; for an energetically heterogeneous surface, the energy of fixation is often assumed to be exponentially related to the number of fixed atoms. The non-uniformity of metallic surfaces in adsorption has been demonstrated by the differential isotope method; by the autoradiographic technique of Tammann, the radioactive tracer can be exactly located. Results on isotopic exchange at a metal surface in contact with a solution of its own ions are discussed. Some examples are given of the use of radioindicators in the study of corrosion. Radioactive methods are particularly suitable for the study of condensation and vaporization of monomolecular layers. Practical applications to the study of friction and lubrication are considered. Suggestions are made for further investigations. 67 references.—MA. 11511

2.3.9, 3.7.3, 5.3.4

Surface Metallography Solves Production Problems. A. T. STEER. *Am. Machinist*, **99**, No. 27, 109-120 (1955) Dec. 19.

Reasons for failure due to cleaning operations, localized work hardening, or incorrect surface finish occur in very shallow zone 0.0001 to 0.001-inch inward from surface. High magnification photomicrography technique (2000 and 3000 times) is discussed. Selection and preparation of specimen, metallographic polishing compound and polishing procedure, surface examination technique and surface flow caused by polishing are covered. Plating failure traced to poor cleaning is illustrated with photomicrographs of 60-40 brass watchbands electroplated with heavy nickel followed by thin chromium plate. Zone of corrosive interfacial attack and section of plating exfoliation are shown. Production and research problems discussed are fatigue and microcracking from micro-stress risers as in turbine-blade failures; determining type of surface that give continuous plating as illustrated by nickel plate on 70-30 brass sheet where proper etching solved problem; and examination of dual-metal section of nickel-plating on 1 nickel-0.25 carbon steel piston rod to repair worn part where Brownian particles in plating solution caused porosity of plate. Photomicrographs.—INCO. 11551

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.1, 6.2.1, 1.4

The Corrosion Products of Iron and Steel: A Selected Bibliographic Survey with Abstracts. MARY JO HOEHM, compiler. Bibliography No. 3, 1955, 24 pp. Available from: Naval Research Laboratory, Washington, D. C.

Covers period from January, 1945 to January, 1955.—MR. 11548

3.2.2, 2.3.2

Corrosion. MARS G. FONTANA. *Ind. and Eng. Chem.*, **48**, Pt. 1, 87A-89A (1956) March.

Fifteenth of a series of columns on corrosion testing describes pitting and intergranular attack. Photographs.—BTR. 11566

3.2.2, 3.7.4

Atmospheric Corrosion by Nuclei. R. ST. J. PRESTON AND B. SANYAL. *J. Applied Chemistry*, **6**, 26-44 (1956) January.

Experimental study of the mechanism of filiform corrosion, a type of metal corrosion in which narrow filaments grow from nuclei. Graphs,, micrographs, tables. 13 references.—BTR. 11612

3.2.3, 3.5.9, 1.6, 3.2.2

Basic Effects of Environment on the Strength, Scaling, and Embrittlement of Metals at High Temperatures. ASTM Special Tech. Pubn. No. 171, Feb., 1955, 114 pp. Available from Am. Soc. Testing Mat'ls., 1916 Race St., Philadelphia 3, Pa.

Papers and discussions at Cincinnati (Ohio, U.S.A.), February 2, 1955, meeting include: The Role of Thin Surface Films in the Deformation of Metal Monocrystals, J. J. Gilman (pp. 3-13: a survey with 27 references: examples quoted are zinc with copper surface film compared with etched zinc, and oxide coated cadmium crystals); Structure of Oxides Formed on High-Temperature Alloys at 1500 F (816 C), J. F. Radavich (pp. 14-34: various high-alloy steels and one nickel-base alloy); Effect of Strain on the Oxidation of Nickel-Chromium Heater Alloys,



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- Structural Factors Associated with the Stress Corrosion Cracking of Homogeneous Alloys —W. D. Robertson, Robert Bakish
- Stress Corrosion Cracking in Homogeneous Alloys—L. Graf
- Metallurgical Aspects of Stress Corrosion Cracking in Aluminum Alloys—E. C. W. Perryman
- The Mechanism of Stress Corrosion Cracking Observed in a Magnesium Alloy—D. K. Priest
- The Role of Boundary Adsorption in Stress Corrosion Cracking—Rudolph Speiser and J. W. Spretnak
- Stress Corrosion Cracking of Austenitic Stainless Steels in Aqueous Chloride Solutions—T. P. Hoar, J. G. Hines
- The Phenomena of Stress Corrosion Cracking in Austenitic Stainless Steels—C. Edeleanu

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E. A. Gulbransen and K. F. Andrew (pp. 35-48: use of new test method "strain oxidation"; resistance of alloys to stress during oxidation shows good correlation with ASTM useful life tests); An Investigation of the Intergranular Oxidation in Type 310 Stainless Steel, R. E. Keith, C. A. Siebert and M. J. Sinnott (pp. 49-64); The Properties of Oxidation-Resistant Scales Formed on Molybdenum-Base Alloys at Elevated Temperatures, M. Gleiser, W. L. Larsen, R. Speiser and J. W. Spretnak; Oxidation at Elevated Temperatures, J. F. Radavich (pp. 89-114: various high alloy steels and one nickel-base alloy). Discussions are included.—BNF. 11697

3.5 Physical and Mechanical Effects

3.5.8, 3.7.3

Fatigue Strength and Surface Finish. M. Hempel. *Draht,* English Edition No. 17, 15-19 (1955) June.

A survey of knowledge on steel, based on 38 references (mainly German). Surface condition, surface roughness, reduction of fatigue strength by electrodeposits, improvement of fatigue strength by shot peening, effect of electropolishing.—BNF. 11066

3.5.8, 6.2.3, 6.6.5

Stress-Corrosion and Relaxation of High Carbon Steel Wire for Prestressed Concrete. F. Schwier. Paper before Wire Assoc., Ann. Mtg., Chicago, Nov. 16, 1955. *Wire & Wire Products,* **30,** No. 12, 1437-1479, 1519-1521 (1955) Dec.

Resistance to stress corrosion and the relaxation of several high tensile steels for wire and strands used in prestressed concrete were investigated. Oil tempered wires are considerably less resistant to stress corrosion than drawn and stress-relieved steel wires. This is due to martensitic condition of steel (high inner stresses) and its crystal structure (great number of grain boundaries). Fatigue tests confirm that stress corrosion attack in drawn and stress relieved steels is less, even at longer corrosion times. Relaxation studies at various stresses after 1000 hours for drawn as well as drawn and stress-relieved wires and strands show them to be particularly suited at stresses below 70 percent of the ultimate tensile strength drawn. Favorable influence of a low reduction in area in drawing was found. Low manganese and silicon alloyed carbon steel wires in stress relieved condition exhibit particularly favorable creep behavior. Graphs, stress-strain diagrams.—INCO. 10979

3.5.9

Oxidation at Elevated Temperatures. J. F. Radavich. Paper before Am. Soc. Testing Materials Symp. on Basic Effects of Environment on the Strength, Scaling, and Embrittlement of Metals at High Temperatures, Cincinnati, February 2, 1955. ASTM Special Technical Pubn. No. 171, 1955, 89-113; disc., 113-114.

Under the sponsorship of Inco and the direction of V. N. Krivobok and C. R. Mayne, a project was undertaken to study the initial oxidation of various high-temperature alloys (19-9 DL, Types 347, 310, 316 Cb and 17-14 Cu Mo, N-155 and Hastelloy C) using electron microscopy, reflection electron diffraction, transmission electron diffraction, X-ray diffraction and X-ray spectography. Studies were made at 600 and 815C. Detailed study was made of the initial oxide growth on the alloys by means of electron microscopic examination of surface replicas and stripped oxide films. Electron microscopic studies of the oxide growth occurring on one region after repeated oxidations are presented for N-155 and a typical iron-chromium-nickel alloy. Analysis of the structure and the identification of the oxide film formed on the seven alloys are given. Photomicrographs and 10 references.—INCO. 1095

3.5.9, 3.8.4, 6.2.2, 3.7.3

The Precipitation of Fe_3O_4 in Scale Formed by Oxidation of Iron at Elevated Temperatures. (In French.) J. Paidassi. *Acta Metallurgica,* **3,** No. 5 447-451 (1955) September.

Study of the quenching of scales formed by direct oxidation of iron in air or of those resulting from the oxidation of existing films after detachment from their metallic support leads to the following conclusions. The precipitation of Fe_3O_4 which can be observed in the layer of ferrous oxide of the scales forms only during their cooling down by decomposition of the monoxide. It is more difficult to prevent this decomposition if the temperature of oxidation or re-oxidation is very high and when this temperature is above 980C, the most energetic quenching does not prevent the beginning of precipitation. The concentration of oxygen in ferrous oxide rich in oxygen is the predominating factor in their instability during rapid cooling, whether by quenching or by cooling in air. When the former scales are cooled in air the precipitation of Fe_3O_4 in the layer of monoxide presents a certain number of peculiarities which can be explained by taking into account previous results and making some simple hypotheses.—INCO. 10923

3.5.9, 4.3.3

Influence of Vanadium Pentoxide on the High-Temperature Scaling of Heat-Resisting Alloys. W. Betteridge, K. Sachs and H. Lewis. *J. Inst. Petroleum,* **41,** 170-180 (1955) May.

Report scaling tests without stress on nickel-chromium heat-resisting alloys, austenitic stainless steels and a cobalt-base alloy, effects of corrosion on high-temperature properties (stress-rupture tests) and microscopic studies. It seems probable that protective oxide layers are removed by solution in vanadium pentoxide. Tests on pure nickel show that oxidation rate is not increased by vanadium pentoxide: would seem to indicate that nickel oxide is not fluxed by vanadium pentoxide at 850C and is valuable constituent in scale. Results indicate that nickel-chromium base alloys are more resistant to effects of corrosion by vanadium pentoxide-sodium sulfate mixtures than are iron-base alloys or the cobalt alloy.—INCO. 9936

3.5.8, 6.2.5, 1.3

Stress-Corrosion of Stainless Steels. J. J. Heger. *Metal Progress,* **67,** No. 3, 109-116 (1955) March.

A survey of current knowledge. Service failures in a variety of environments, with extended discussion for presence and absence of chlorides; results of laboratory investigations; methods of preventing stress-corrosion, including correct choice of steel, improved design and operation, stress-relieving, shot-peening, use of inhibitors or cathodic protection. —BNF. 10065

3.5.1, 2.3.9

Trends in Metallurgical Research in the United States. E. C. Bain. *J. Iron*

Steel Inst., **181**, No. 3, 193-212 (1955) Nov.

Eighth Hatfield Memorial Lecture: A review of some of the researches in progress: x-ray metallography, x-ray fluorescence analysis, martensitic transformation in sodium, nature of martensite, boron steels, electron metallography and extraction replica technique, mechanism of diffusion, dislocations, growth spirals, whiskers, metallographic aspects of fatigue, machinability, deformation and brittle fatigue, zone melting, thermodynamics, physical chemistry of steel making. 106 references.—BNF. 11693

3.5.3

Cavitation. (In Norwegian.) INGVAR EGGESTAD AND CARSTEN D. LOVSTAD. *Tek. Ukeblad*, **103**, No. 5, 83-92 (1956) Feb. 2.

Investigation on steel and nonferrous metals; factors contributing to cavitation; scale effect; effect of hydrodynamic properties. Graphs, tables. (To be continued.)—BTR. 11582

3.5.3, 2.3.7, 6.2.1

Erosion of Steel by Hot Gases. M. J. FRASER AND A. A. BURR. *J. Electrochem. Soc.*, **103**, No. 4, 224-231 (1956) April.

A vent-plug device for producing eroded surfaces on steel and other metals is described. Surfaces so treated have been shown by metallographic and x-ray analysis to duplicate structures encountered in many service applications. During the erosion of steel, as many as five distinct surface layers are produced. Retention of austenite in these eroded surfaces is an indication of the chemical alteration of the surface layers during erosion. The major portion of the investigation is concerned with a modified SAE 4330 steel. However, comparison experiments were made on Armco iron and SAE 1015, 1040 and 1070 steels. The effect of carbon content on erosion behavior is illustrated by x-ray analysis. 11629

3.5.6, 6.3.10, 6.3.6

The Influence of Thin Intermediate Layers on Interdiffusion in Copper-Nickel Couples. M. L. MEHTA AND H. J. AXON. *Acta Metallurgica*, **3**, No. 6, 538-541 (1955) Nov.

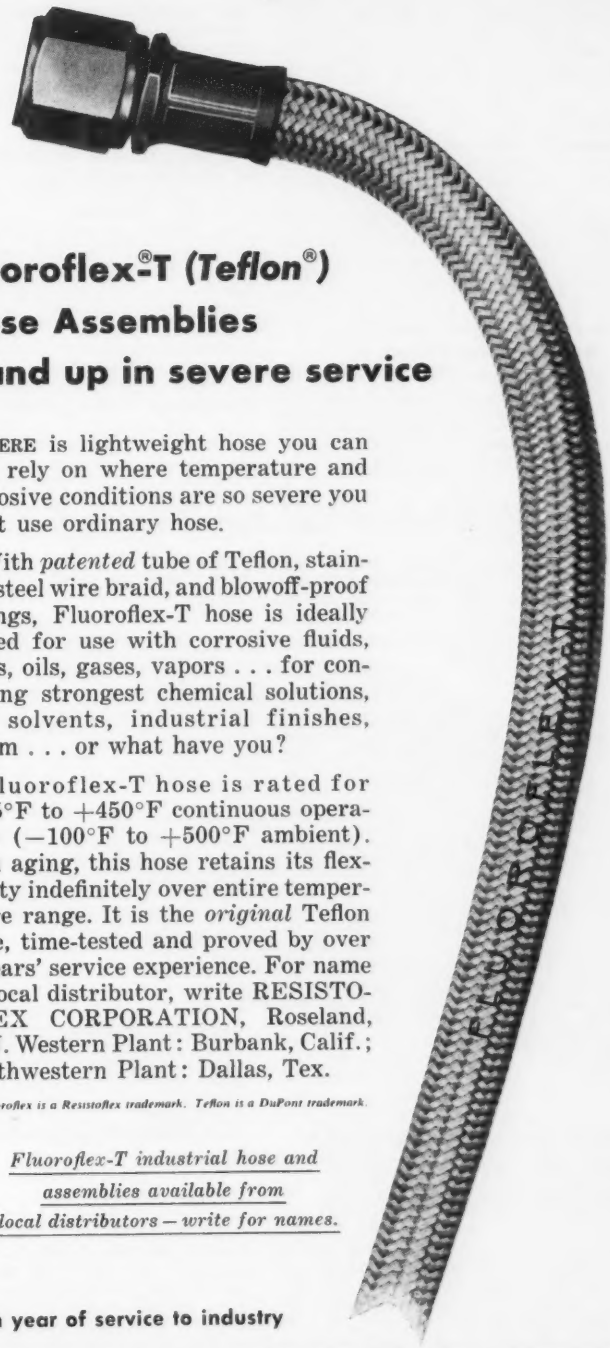
Experiments on the chemical diffusion coefficients in the copper-nickel system for the two pure metals and with the presence of thin intermediate layers of gold, tin, zinc or cadmium. Gold or zinc has small effect while tin or cadmium accelerates the rate of diffusion. Tin behaves differently from cadmium in accelerating the diffusion of nickel into copper and retarding that of copper into nickel. 8 references.—INCO. 11526

3.5.8, 1.6

Failure of Materials Under Combined Repeated Stresses with Superimposed Static Stresses. G. SINES. National Advisory Cttee. for Aeronautics, Tech. Note No. 3495, November, 1955, 69 pp.

Review of experiments on biaxial alternating stresses and simple combinations of static stress with alternating stress leads to general criterion for effect of static stress on permissible amplitude of alternating stress. Proposed criterion agrees with results of tests performed under more complex stress states. Tests were performed on aluminum alloy specimens to determine effect of static compression on alternating torsion, a combination not previously investigated. Modification of Orowan's theory of fatigue to include effect of static stress is presented. Investigations by H. J.

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Gough on nickel-chromium-molybdenum steel are among those discussed. Graphs, tables, 45 references.—INCO. 11533

3.5.8, 6.2.5

The Stress-Corrosion Cracking of Austenitic Stainless Steels. Part I. Mechanism of the Process in Hot Magnesium-Chloride Solutions. T. P. HOAR AND J. G. HINES. *J. Iron Steel Inst.*, **182,** 124-143 (1956) Feb.

Several types of stainless steel wires based on 18% chromium-8% nickel, stressed in tension, were exposed to 42% aqueous magnesium chloride solution at 135-154 C. Corrosion potential and extension were measured. Diagrams, micrographs, tables, graphs. 33 references.—BTR. 11638

3.5.8, 8.9.1

Fatigue in Aircraft Structures. (In French.) W. BARROIS. *Metaux, Corrosion-Industries,* **30,** No. 364, 484-504 (1955) Dec.

Repeated loads encountered during service; fatigue of notched parts; fatigue resistance of aircraft structures and calculation of damage due to loading—BNF. 11692

3.7 Metallurgical Effects

3.7.2, 6.4.2, 6.4.4, 5.3.2

The Use of Beryllium (Additions) in Light-Metal Alloys. E. A. SMITH, JR. AND E. A. GIESSEN. *Metall,* **9,** No. 5/6, 198-199 (1955).

A brief summary of the effects of small additions (generally in the region of 0.0005-0.02%) of beryllium on the melting, casting, structure, mechanical properties and corrosion-resistance of aluminum-magnesium and magnesium-aluminum alloys and on the formation of hot-dipped aluminum coatings on steel. 7 references.—MA. 11568

3.7.3

Some Factors Affecting Design of Aluminium-Alloy Fabrications Welded by the Inert-Gas-Shielded Arc Process. A. L. HALE. *Brit. Welding J.*, **2,** No. 10, 455-458 (1955).

The mechanical, corrosion and welding properties of medium- and high-strength aluminum alloys are reviewed and the effect of welding in reducing the strength to that of annealed sheet is emphasized. Welds should be located so that they are remote from zones of maximum stress and should not introduce stress concentration. Welding is expensive and full use must be made of the wide variety of extruded sections available to reduce the number of welds to a minimum. Joints must be assembled so that there is some support for the weld pool; a copper backing bar can be used, but it is often possible to design the joint in such a way that the pool is supported by the parent metal.—MA. 11519

3.7.3, 3.5.9

Oxidation Resistant Brazing Alloys. (Period covered June 30, 1953 to December 31, 1954). GEORGE H. SISTARE, JR. AND ALLEN S. MCDONALD. Handy and Harman, Bridgeport, Conn. U. S. Wright Air Development Center, Tech. Rept. 55-22, April, 1955, 44 pp.

Some 117 experimental brazing alloys were prepared at the Handy and Harman research laboratories and evaluated as possible candidates for joining heat conducting metal fins to Inconel tubing for service at temperatures in the order of 1400 to 1600 F where oxidation resistance of the joint was mandatory. Alloys of gold-nickel-chromium and palladium-nickel base alloys with chromium and silicon were developed which can be used to join stainless steel to Inconel at brazing temperatures in the range of 1900 to 1950 F. The alloys can be torch brazed using flux or used without flux in a protective atmosphere. The resulting joints resist oxidation at 1600 F service temperature. It is still possible that with further development palladium-nickel base alloys with silicon-phosphorus-boron additions can be produced which will braze in the temperature range from 1850 to 1900 F. A note on graphic brazing is included. (auth).—NSA. 11531

3.7.3, 2.3.7

Investigation of Weld-Metal Cracking in High-Strength Steel. R. P. SOPHER, A. J. JACOBS AND P. J. RIEPPEL. Paper before Am. Welding Soc., Nat'l Spring Mtg., June 7-10, 1955. *Welding J.*, **34,** No. 11, 544s-552s (1955) November.

Special apparatus developed to study basic causes of cracking in high-strength weld metals. Hot-tension properties were determined during cooling down from molten state and hot-cracking resistance was studied with relation to composition variables. Study of carbon, sulfur and phosphorus variations in SAE 43XX-type weld metals shows that increase of these elements has adverse effects on hot-tension properties and hot-cracking resistance. Sulfur and phosphorus are more detrimental than carbon. Promising possibility exists that high-carbon (low in phosphorus and sulfur) filler wire can be deposited under conditions of restraint and weld metal then heat treated with base plate to high-strength levels for commercial applications. Explanation for hot cracking is suggested in terms of typical hot strength and ductility curves. Photomicrographs of SAE 4340 weld deposits and hot-tension specimens show slight but definite association between intergranular eutectics in tension specimens and poor hot ductility. Diagrams of test apparatus, graphs, photomicrographs.—INCO. 11529

3.7.3, 6.2.5

Joint Design for Joining Tubes to Tube Sheets for Corrosive Radioactive Chemical Service. W. R. SMITH. Hanford Atomic Products Operation, Richland, Washington. U. S. Atomic Energy Commission Pubn., HW-37983, August 18, 1955, 18 pp.

Stainless steel tubes have been joined to tube sheets by a fabrication method which combines welding and rolling techniques. Results of corrosion studies indicate that the joints were as corrosion resistant as the base materials.—NSA. 11509

3.7.3, 6.3.10

"Cold Weld" Nickel Alloys for Atom Plant Use. E. NUTTER. *Iron Age,* **177,** No. 7, 111-113 (1956) Feb.

Metal apparatus in atomic energy plants under severe pressures and temperatures in highly corrosive atmospheres requires the use of a special nickel alloy. Since nickel alloy weld metal does not spread well and has shallow penetration characteristics, the "Cold Weld" technique is used. A high temperature stabilization process is used to give hot worked nickel alloy the stress relief to develop the best combination of strength and ductility and also to insure against any distortion and warping during subsequent machining.—INCO. 11625

3.7.4

Grain Boundaries, Substructures and Impurities. R. W. CAHN. "Impurities and Imperfections" (Am. Soc. Metals), 1955, 41-83.

The properties of grain boundaries (mechanical properties, melting point, corrosion-resistance, etc.) and the effects of impurity atoms, vacancies and dislocations on these properties are discussed. Substructures generated by hot or cold work, recovery, recrystallization, or phase transformation and the interaction of the sub-boundaries with impurities are described. The two types of boundary are compared. 121 references.—MA. 11702

3.8 Miscellaneous Principles

3.8.2, 6.3.11, 3.2.3

The Kinetics of the Formation of β-Silver Sulphide and Its Relation to Phenomena of Electrochemical Corrosion. M. BILLY AND G. VALENSI. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 371-384; disc., 385-386.

It is suggested that macroscopic processes should be regarded as electrochemical if at least one step implies a transport of ions in the bulk of a phase with rates algebraically different for anions and cations of each participating electrolyte. The attack of silver wire by liquid and gaseous sulfur was studied by measuring the change of electrical conductance. Results with liquid sulfur are reported for 135-173 C; the isotherms show that diffusion controls the rate; the variation with temperature indicates formally an enthalpy of activation of 21,700 cal./g.-mol. Results with sulfur vapor are reported for 140-170 C; from the isotherms it is concluded that the external interfacial reaction and diffusion are both important in controlling the rate; a mathematical analysis of the variation with temperature shows the diffusion rate to be the same as with liquid sulfur and gives an enthalpy of activation of 16,000 cal./g.-mol. for the interfacial reaction. The diffusion rate is in excellent agreement with Wagner's theory. 28 references.—MA. 11725

3.8.3, 6.2.1, 3.7.2

The Passivity of Iron-Chromium Alloys. R. OLIVIER. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 314-331; disc., 332-333.

It is shown that, when iron-chromium alloys are passivated by anodic solution, the product of current density and passivating time is constant, being equivalent to an amount of coulombs/cm.^{2} needed for reaching passivity; this amount decreases with increasing chromium content of alloy up to 14%, but remains the same for 14-18% chromium. The passivity of iron-chromium alloys is due to an oxide layer, the potential of formation of which is lower the higher the chromium content; with increasing chromium, the oxide becomes more stable towards sulfuric acid and its reduction by local cell action becomes more difficult. When a passive iron-chromium alloy is put into an acid solution, any bare metal under a hole in the oxide layer forms an anode, but a local-cell generation of only ~0.01 coulombs/cm.^{2} is sufficient to repassivate the bare spot, provided that the current density is

greater than the limiting current density for the alloy. This picture holds also for 18:8 stainless steel.—MA. 11515

3.8.4, 3.2.3
Oxidation of Bi_2SE_3 and Bi_2Te_3 Specimens During Heating in Air. (In Russian.) S. A. SEMILETOV AND Z. G. PINSKER. *J. Technical Physics, USSR* (Zhur. tekh. fiz.), **25,** No. 13, 2336-2338 (1955) Nov.

Electronographic study of structure of thin layers formed by sublimation. Table. 2 references.—BTR. 11522

3.8.4, 3.2.3
The Gas-Oxide Interface and the Oxidation of Metals. T. B. GRIMLEY AND B. M. W. TRAPNELL. *Proc. Roy. Soc.,* **234,** Ser. A, 405-418 (1956) Feb. 21.

Emphasizes importance of structure of the surface layer of oxygen adsorbed at the oxide-oxygen interface in determining the laws of growth of thin oxide films on metals. Graph. 17 references.—MR. 11632

3.8.4, 6.3.6
Oxygen-18 Isotope Effect in the Reaction of Oxygen with Copper. RICHARD B. BERNSTEIN *J. Chem. Phys.,* **23,** 1797-1802 (1955) October.

The fractionation of O^{18} in the reaction of copper with oxygen of natural isotopic composition has been measured over the temperature range 68 to 256 C. The oxide films (estimated thicknesses varying from 150 to 2500 Å) were removed for O^{18} assay by treatment with hydrogen at 350 C. Using the carbon dioxide equilibration technique, the O^{18}/O^{16} ratios for the resulting water samples were determined mass spectrometrically and compared with the ratio for a reference sample of water prepared from the original oxygen. The direction of the fractionation indicated that O^{16} reacts preferentially compared to $O^{16}O^{18}$. The isotope effect appeared to be independent of the oxygen pressure over the limited range studied (2 to 25 cm.Hg). The magnitude of the fractionation factor was 2.0% at 150 C, with a small negative temperature coefficient. From this it was possible to estimate a value of $\Delta E_{act} = 17$ cal/mole, which may be compared with the calculated isotopic zero-point energy difference of 64 cal/mole. The theoretical implications of the experimental results are discussed. (auth).—NSA. 11687

4. CORROSIVE ENVIRONMENTS

4.4 Chemicals, Organic

4.4.5, 3.7.3
Corrosion Studies on Aerosol Containers. R. A. FULTON. Paper before Chemical Specialties Mfrs. Assn., 42nd Ann. Mtg., N. Y., December 7, 1955. *Soap and Chemical Specialties,* **32,** No. 2, 163, 165, 193 (1956) Feb.

Methyl chloride, commonly used propellant for greenhouse aerosols, corrodes container if it contains 0.03% moisture, with severe corrosion occurring with 0.05% moisture. With DDT present in aerosol solution, initial corrosion reactions starts secondary corrosion reaction by removing hydrochloric acid from DDT molecule. Hydrochloric acid formed from ammonium chloride contained in acid soldering flux causes corrosion of fuse plugs. Tests with aluminum, brass and steel valve bodies are discussed. Effects of zinc, nickel, chromium, tin and organic coatings are summarized.—INCO. 11631

4.4.6, 4.4.9
How's Your Fuel Oil Quality? J. P. KIRCHNER, D. P. OSTERHOUT AND W. R. SCHWINDEMAN. Socony Mobil Oil Co. *Petroleum Processing,* **11,** No. 1, 67-71 (1956) Jan.

Basic causes of sludge and gel formation and their elimination. Sludge problem, caused by unstable fuels, is remedied by use of anti-screen-clogging additives, sediment inhibitors and refining procedures. Copper mercaptide gel is caused by reaction of mercaptans in fuel with copper in the brass parts of the system. Deposits resemble small lumps of amber-colored jelly adhering to brass parts and clogging interior of brass nozzle filters. Mechanism is corrosion attack on brass to release copper ions. Attack does not occur on copper which tarnishes quite readily and may make it less subject to attack by mercaptans. Refining techniques convert mercaptans into harmless compounds.—INCO. 11599

4.5 Soil

4.5.2
Laboratory Investigation of the Corrosive Effect of Various Types of Soils. Part I. Denison-Cell Investigations. (In Hungarian.) MIHALY SOLTI AND JOZSEF HORVATH. *Hungarian Journal of Chemistry* (Magyar kemiai folyoirat), **61,** No. 12, 427-437 (1955) Dec.

Corrosivity of nine different types of



soils investigated with steel electrodes in a modified Denison cell. Tables, graphs, micrographs, diagrams. 18 references.—BTR. 11530

4.6 Water and Steam

4.6.2, 6.2.4

Modern Pipe Materials—Key to Today's Better Steam Stations. E. A. STICHA. *Power*, **99**, No. 7, 86-88, 188, 190 (1955) July.

Summarizes experience in use of chromium-molybdenum steels for steam piping. Failures in carbon-molybdenum steels were due to graphitization and addition of chromium proved only practical answer to providing carbide stability. Steam-power industry has practically standardized on chromium-molybdenum steels containing 1-1¼ chromium for 850-1000 F while above 1000 F steels with 2¼-3 chromium are preferred. 18-8 steels were originally utilized because of superior corrosion resistance but they are susceptible to sigma phase formation inducing embrittlement. Table gives chemical composition of high-temperature pipe steels (ASTM A335 and A217). Graphs, photomicrographs.—INCO. 11553

4.6.2, 7.6.4

Return Lines Failing? Identify the Cause Before Prescribing Treatment. J. R. COURSAULT. W. H. & L. D. BETZ. *Power Eng.*, **60**, No. 2, 66-67 (1956) Feb.

Corrosion of condensate return lines of boiler systems due to oxygen and carbon dioxide. Attack by dissolved oxygen is characterized by pits and build-up of iron oxide deposits, while carbon dioxide attack is characterized by grooving and actual thinning of walls. Prevention of corrosion by deaeration, chemical inhibitors, reduction of alkalinity and filming or neutralizing amines is discussed.—INCO. 11584

4.6.5, 6.3.6

Effects of Softened Water on Equipment. LORING E. TABOR. *J. American Water Works Association*, **48**, 239-246 (1956) March.

Serious dezincification of value stress is caused by softening. Low-zinc bronzes are now specified. Tables, graph, diagrams. 1 reference.—MR. 11650

4.6.6, 4.6.7, 8.1.4

Effects of Water Quality on Various Metals. LEE STREICHER. *J. American Water Works Association*, **48**, 219-238 (1956) March.

Effects of Colorado River water on corrosion of several subscribing municipal systems. Tables, graphs, photographs. 3 references.—MR. 11654

4.6.8, 2.2.7, 2.2.3

Corrosive and Erosive Effects of Acid Mine Waters on Metals and Alloys for Mine Pumping Equipment and Drainage Facilities: Anthracite Region of Pennsylvania. S. H. ASH, H. A. DIERKS, E. W. FELEGY, K. M. HUSTON, D. O. KENNEDY, P. S. MILLER AND J. J. ROSELLA. Dept. of the Interior, Bureau of Mines Bull. No. 555, 1955, 46 pp.

Volumes of mine water from various mines were pumped and stored. Data on volume and quality of this water and on corrosion- and erosion-resistant properties of 25 metals and alloys exposed to attack by most highly acid mine water were obtained. Corrosion tests employed utilized weight loss and microscopic examination methods. Program consisted of immersion tests with spool-type specimen holders suspended in sumps, main pump discharges or flumes from pump discharges to receiving streams and revolving-spindle tests to study effects of velocity and abrasive particles on corrosion. Analyses of precipitated material called yellow boy showed it was composed of corrosion products of tin, lead and copper with all sulfur present as sulfate. Unidentified amorphous material is assumed to be intermediate state of ferrous sulfate to ferrous sulfide reaction. Types 302, 303, 304, 316, 410, 430, 446, 17-4 PH and 17-7 PH, cast stainless steels ACI CE30, CF8M, and HC and titanium have adequate corrosion resistance to severely corrosive acid mine waters in the anthracite region. 89-2-9 copper-lead-tin bronze showed a corrosion rate ¼ that of 75-15-10 bronze generally in use. Increase of lead content of bronze appears to increase corrosion rate. All aluminum bronzes (nickel containing) had corrosion rates equal to or higher than 75-15-10 bronze. Type 1020 steel and 5 chromium-0.1 nickel steel dissolved completely within 19 days. Thin specimens of Type 304 were tested to determine if low chloride content of water (14-18 ppm) would promote cracking. Despite high and possibly alternating stresses, no evidence of stress corrosion or corrosion-fatigue cracks was observed. Report is based on field tests conducted cooperatively by Armco Steel Corp. and the Bureau of Mines. Tables, graphs, photomicrographs, photographs of specimens (some colored), 93 references.—INCO. 11681

4.6.11, 2.2.7, 6.4.2

Corrosion on Light Alloy Structural Parts of the Superstructure of a German Naval Escort Vessel Sunk During the War. P. BRENNER, F. E. FALLER AND T. DOMES. *Forschungshefte fur Schiffstechnik*, **2**, No. 10, 165-170 (1955) July; translation: Aluminium Development Assoc. Tech. Memo. No. 300.

Superstructure was installed in 1939; vessel was submerged in harbor water from 1945 to 1952. Light alloy parts were relatively well preserved, clad Duralumin-type sheet (anodized and painted) having scarcely corroded at all. Painted aluminum-silicon castings and unprotected 99.5% aluminum sheet were second in corrosion resistance. Sections and rivets of aluminum-7 magnesium suffered badly from pitting and intergranular corrosion.—BNF. 11711

4.6.12, 5.8.2

Application of Organic Inhibitors in Water-Flooding. J. B ROBINSON. Tretolite Company. *World Oil*, **142**, No. 2, 156, 159-160, 162 (1956) Feb. 1.

Use of water soluble liquid, semi-polar organic compounds to treat floodwater systems has resulted in decrease in equipment corrosion, improved control of bacteria, decrease of corrosion product deposition at injection well face and decrease in interfacial tension. Results are presented for corrosion test coupons installed at various points throughout system.—INCO. 11664

4.7 Treatment of Medium

4.7

Behavior of Materials in Nonaggressive Liquid Metals. EDWIN G. BRUSH AND ROBERT F. KOENIG. Paper from Nuclear Metallurgy, IMD Special Report Series No. 2, 1956, 21-23. American Institute of Mining and Metallurgical Engineers, New York.

Discusses the nonaggressive liquid metals which are of greatest interest for nuclear power plants: sodium and sodium-potassium alloys. Graphs, tables, micrograph., 13 references.—BTR. 11552

4.7

Fundamentals of Liquid Metal Corrosion. W. D. MANLY. *Corrosion*, **12**, No. 7, 336t-342t (1956) July.

The corrosion of structural metals in liquid metals is for the most part the result of solubility of the various constituents of the metal or alloy in the liquid metal. The manner in which this solution manifests itself gives rise to many types of attack, ranging from a simple solution type attack to a deep intergranular attack with the preferential leaching of one constituent of an alloy. Examples of the many types of corrosion experienced with solid metal-liquid metal systems are illustrated. The role of impurities on corrosion is discussed.

In addition to the solution stage, which would soon disappear in a static one metal system on reaching a solubility limit, the corrosion of metals can be continued through the removal of materials from solution in the liquid metal with a temperature gradient or by dissimilar metal transfer. The transfer of metal in a plumbing system by the mechanisms of mass transfer—temperature gradient and dissimilar—will greatly increase the amount of corrosion as compared to the results obtained in static systems. Examples of temperature gradient mass transfer and dissimilar metal transfer are reviewed, and factors governing the occurrence of these phenomena are outlined. 11657

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 5.4.5, 8.9.3

The Water Engineer and Cathodic Protection. K. A. SPENCER. *J. Inst. Water Engrs.*, **10**, 51-57; disc., 76-103 (1956) Feb.

Deals with bituminous-type coatings and cathodic protection for the exterior of buried metal pipelines, with special reference to their technical and economic advantages. Tables, photographs, graphs, diagrams. 10 ref.—BTR. 11672

5.2.1, 7.7

Cathodic Protection of Lead Cables in an Urban Area. L. M. PLYM. *Corrosion*, **12**, No. 7, 331t-335t (1956) July.

An account is given of steps taken in establishing a cathodic protection system for lead covered telephone cables in an urban area. Practical applications for the following system arrangements are given: Distributed ground beds, forced current through a drainage system, distributed negative connections to several underground cables and duct anodes. The paper includes the steps taken to prevent damage to surrounding underground plants in the installation and use of these systems. 11662

5.2.1, 8.1.4

Where Cathodic Protection Works. F. W. SHANKS AND J. L. ROHWEDDER. *Eng. News-Record*, **156**, 33-34, 36 (1956) March 15.

Corrosion of immersed steel struc-

tures often can be mitigated more economically by cathodic protection than by other means. This finding applies chiefly to the miter and sector gates of navigation locks. Test results. Photographs.—BTR. 11678

5.2.1, 8.4.3

Corrosion and Cathodic Protection in Kuwait. J. S. GERRARD. *J. Inst. Elec. Engrs.*, **2**, 2-6 (1956) Jan.

Discusses principles and methods of cathodic protection against corrosion and measures taken to protect oil installations. Diagrams, photographs, graph.—BTR. 11630

5.2.2

Cathodic Protection: Use of Magnesium Anodes. M. BERNARD AND J. C. RACLOT. *Bull. Soc. Franc. Elec.*, **5**, No. 49, 9-18 (1955) January.

Method of placing separate anodes for external protection of steel pipes and structures immersed in sea and for internal protection of tanks and pumps.—BL. 11696

5.2.2, 4.6.11

The Effect of Iron in Galvanic Zinc Anodes in Sea Water. R. B. TEEL AND D. B. ANDERSON. *Corrosion*, **12**, No. 7, 343t-349t (1956) July.

Sharp decreases in the current output of zinc galvanic anodes in sea water are attributed to the increase in the electrical resistance and tenacity of the corrosion product films which form on the anode's surface. This behavior is influenced largely by the amount of iron present as a minor impurity in the zinc. Iron content should be kept below .0015 percent for best results. Zinc containing a higher iron concentration will develop a high resistance corrosion product film which will render the zinc less effective as an anode material. 11661

5.2.3

High-Silicon Cast-Iron Anodes in Ground Bed Service. M. E. PARKER. *Gas*, **32**, No. 3, 141-143 (1956) March.

Presents some case histories on application of Duriron anodes to gas transmission lines (including conditions encountering quicksand) and compares performance of Duriron anodes with that of conventional types in conditions of high or low soil resistivity and wet or dry holes.—INCO. 11628

5.4 Non-Metallic Coatings and Paints

5.4.5, 5.4.10, 8.9.3

Twelve Musts for a Good Pipe Coating Job. MARSHALL E. PARKER. *Pipe Line Ind.*, **4**, 31-34 (1956) March.

Considerations to watch for, starting with storage and handling of materials, continuing during actual application and including handling of coated pipe until it is in the ditch and backfilled. Photographs.—MR. 11610

5.4.5, 6.6.7

Latex-Cement Compositions in Corrosion-Resistant Construction. P. B. CORMAC. *Corrosion Technology*, **3**, Nos. 2, 3, 43-46, 76-78 (1956) Feb., March.

Describes development of latex-cements, their manufacture, corrosion-resisting properties and their application under various service conditions. Under conditions of continuous contact with corrosive agent, latex-cements provide protective barrier as jointless render and as a mortar in construction of brickwork or tiling systems. Priming or filling layers applied to concrete vessels permit protective storage and processing of wine, beer, olive oil, whey and molasses. Use of latex-cement coatings in conjunction with cathodic protection is discussed. Protection of floor structures in industrial plants is considered.—INCO. 11585

5.4.5, 8.9.3

What to Expect from Internal Coatings. J. C. WATTS. *Pipe Line Industry*, **4**, 20-23 (1956) March.

Application, costs, performance, future prospects for internal coatings of pipe lines. Photographs, tables. 5 references.—MR. 11648

5.4.8

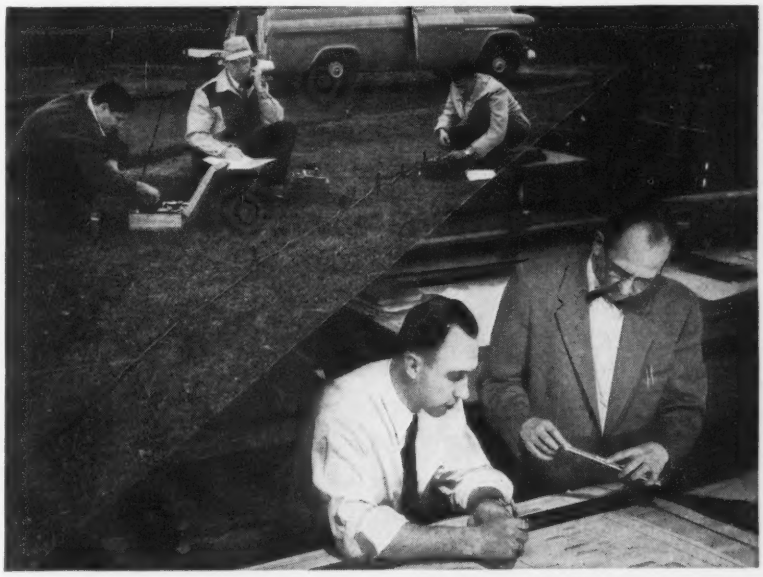
Plastic Coatings for Corrosion Prevention. G. A. CURSON. *Corrosion Prevention and Control*, **3**, 30-34 (1956) Jan.

A tabular guide to types of plastic coatings applicable to the protection against several corrosive agents. Table, photographs.—BTR. 11580

5.4.8, 4.6.11, 8.9.5

Paint for Marine Applications. R. HAMMOND. *Ind. Finishing*, **8**, No. 79, 28-34 (1955) January.

A survey of the causes of corrosion, particularly in marine conditions and of paint systems used for ships. Zinc chromate pigments or zinc-rich paints may be used as corrosion-inhibiting primers, although priming is not necessary on weathered galvanized or metallized surfaces. Zinc chromate painting of the ship's bottom results in a low increase in skin-frictional resistance. In the Anglo-Saxon fleet of 18,000-ton tankers, an alkyd resin containing zinc chromate has been



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adopted as the standard primer for the hull topside and the whole of the superstructure.—ZDA. 11524

5.4.8, 8.9.5

Development of Marine Paints: Recent Progress. A. D. C. HAMILTON. *Ind. Finishing*, **9**, 313-315 (1956) Jan.

Development of new and better types of protective paints, as applicable to requirements for various parts of ships. Photographs.—BTR. 11636

5.5 Oil and Grease Coatings

5.5.3

Temporary Protection Coatings. Part I. Metallic Naphthenate Solutions. E. STRONG. *Product Finishing*, **9**, 65-83 (1956) Feb.

The available temporary coatings for protecting raw material and fabricated parts in manufacturing and assembly are discussed, together with a review of their desirable qualities and a consideration of the possible applications of metallic naphthenate solutions. Diagrams, graphs, micrographs, photographs, tables. (To be continued.)—BTR. 11640

5.5.3, 5.4.6, 2.5

Corrosion-Preventive Compounds. Canadian Government Specifications Board, Specifications 31-GP-o-31-GP-8; British Standards Institute Monthly Inf. Sheet, **1955**, 9-10, October.

This series of specifications covers temporary corrosion preventives of both hard and soft film types, including products based on petroleum and water-displacing products. 3-GP-o comprises a schedule of methods of testing such materials.—RPI. 11713

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5.8 Inhibitors and Passivators

5.8.2

Interpretation of the Operation of Vapor Phase Inhibitors by Observing Their Behavior at Various Temperatures. (In Italian.) C. BIGHI AND G. MANTOVANI. *Metallurgia Italiana*, **47**, No. 11, 505-510 (1955) Nov.

Tests of action of various inhibitors against corrosion by sulfur dioxide. Photographs. 28 references.—BTR. 11720

5.8.2, 2.3.2

Fatty Amines Combat Corrosion. *Progress Thru Research* (Gen. Mills), **9**, No. 4, 3-5 (1955).

Discusses film-forming fatty acid amines and amine derivatives and their use as corrosion inhibitors in steam boiler systems; in acid pickling operations and in fuel oil storage tanks and oil wells. Films formed are monomolecular in thickness. Accelerated laboratory corrosion and inhibition testing set-ups which simulate conditions in these fields are described. —INCO. 11525

5.8.2, 4.6.1

High Activity Alylolamide Detergents. H. L. SANDERS, O. E. LIBMAN AND Y. D. KARDISH. Paper before Chemical Specialties Mfrs. Assoc., 42nd Ann. Mtg., N. Y., December 6, 1955. *Soap & Chemical Specialties*, **32**, No. 1, 33-36, 57 (1956) Jan.

Describes new class of detergents based on condensation of lauric acid and diethanolamine. Unique feature of Ninols is their rust inhibiting power in aqueous solutions. 0.5% Ninol in water gives non-rusting solution.—INCO. 11680

5.8.2, 4.6.1, 8.4.3

Corrosion Inhibitors in Petroleum Refining. P. W. SHERWOOD. *Werkstoffe u. Korrosion*, **6**, No. 1, 2-6 (1955) January.

The theoretical basis of inhibition is briefly discussed and the use of anodic (chromates and nitrites), cathodic (glassy phosphates) and organic inhibitors (sodium benzoate and organic amines in water systems is reviewed, with some details of concentration, temperature, etc. 10 references.—MA. 11542

5.8.2, 8.4.3

How to Get the Most from Your Inhibitor. W. C. KOGER. Cities Service Oil Co. *World Oil*, **142**, No. 4, 167-168, 170, 172, 174 (1956) March.

Begins with discussion of circulation of well fluid in three types of wells—high working fluid level wells producing high percentage of salt water, low working fluid level wells and wells that pump off; and then describes series of tests to determine effect of oil soluble-water dispersible inhibitors and oil insoluble inhibitors. Distribution of corrosion inhibitor in well effluent was measured by induced radioactivity. Oil soluble inhibitors travel in bands in well fluid and weighted oil insoluble inhibitors will fall through oil column in the annulus without flushing. Graphs.—INCO. 11601

5.8.2, 8.4.3, 5.7.7.

Use of Organic Corrosion Inhibitor in Refining Processes. CHARLES FISKE AND PAUL MERNITZ. *Corrosion*, **12**, No. 7, 350t-354t (1956) July.

An account is given of the use in a refinery of an organic corrosion inhibitor. Conventional ammonia injection to a pH of 8 or more in the receiver waters had provided inadequate protection to the usual sites of aggressive corrosion attack in the crude and synthetic crude fractionators, Admiralty metal exchanger bundles and depropanizer overhead lines. A change from sweet to sour crude sources aggravated the situation.

Corrosion was strikingly reduced by proportioned injection of 20 ppm of inhibitor on crude input, as evidenced by coupon and inspection studies and by daily receiver water iron content. The dosage later was reduced to 618 ppm based on overhead products plus reflux. the best point of injection was found to be the overhead reflux lines. Normal flow of inhibitor apparently is downward. pH must still be maintained at 6.5 to 7.5 by ammonia injection. There have been no discoverable adverse effects on any refinery product at this dosage. While savings of ammonia have been about balanced by the cost of inhibitor, down-time for the pipestill due to restrictions from metallic sulfide accumulation has been cut to 25-35 percent of its former extent. Organic inhibitor has extended the life of the tower several years beyond that expected with ammonia protection alone. 11677

5.8.3

The Mechanism of the Inhibition of Corrosion by the Pertechnetate Ion. Part III. Studies on the Perrhenate Ion. G. H. CARTLEDGE. Oak Ridge National Lab. *J. Phys. Chem.*, **60**, No. 1, 32-36 (1956) January.

It has been shown that the perrhenate ion, ReO^-_4, which is very similar to the pertechnetate ion, TcO^-_4, in most respects, differs from it radically in failing to inhibit corrosion under aerated conditions. Radioactive Re^{186} was used, in part, to eliminate the possibility that the radioactivity of technetium is involved in this difference. Measurements of the electrode potential of electrolytic iron in the presence of potassium perrhenate and sodium sulfate demonstrated the weakness of the ennobling effect of the perrhenate ion in aerated solutions and the greater susceptibility of this effect to competition with the sulfate ion, in comparison with the ennobling effect of the pertechnetate ion. In the absence of air, no ennobling by the perrhenate ion was observed. The results are applied to a discussion of the internal charge distribution of the pertechnetate ion as the source of its action. (auth).—NSA. 11589

5.8.4, 4.3.2

The Influence of Nitrogen-Containing Organic Inhibitors on the Electrode Potential of Steel in Sulfuric Acid. R. N. RIDE. *J. Electrochem. Soc.*, **103**, No. 2, 98-107 (1956) Feb.

Corrosion inhibition of mild steel in 1 N sulfuric acid solutions was studied by observing average corrosion rates and changes in steady-state electrode potentials with 13 compounds. These are aniline, ethylaniline, dimethylaniline, diethylaniline, pyridine, quinoline, quinaldine, β-naphthoquinoline, diethylamine, di-n-butylamine, piperazine, tetramethyldiaminodiphenyl methane and brucine. Graphs present various relationships between efficiency, concentration and electrode potential. Mechanism of inhibition is discussed with reference to nature of adsorption interphase and revised theory of inhibition is proposed. Inhibitor is physically adsorbed as second phase on chemi-sorbed hydrogen film present on the metal. Inhibition is due to increased hindrance to anodic dissolution process

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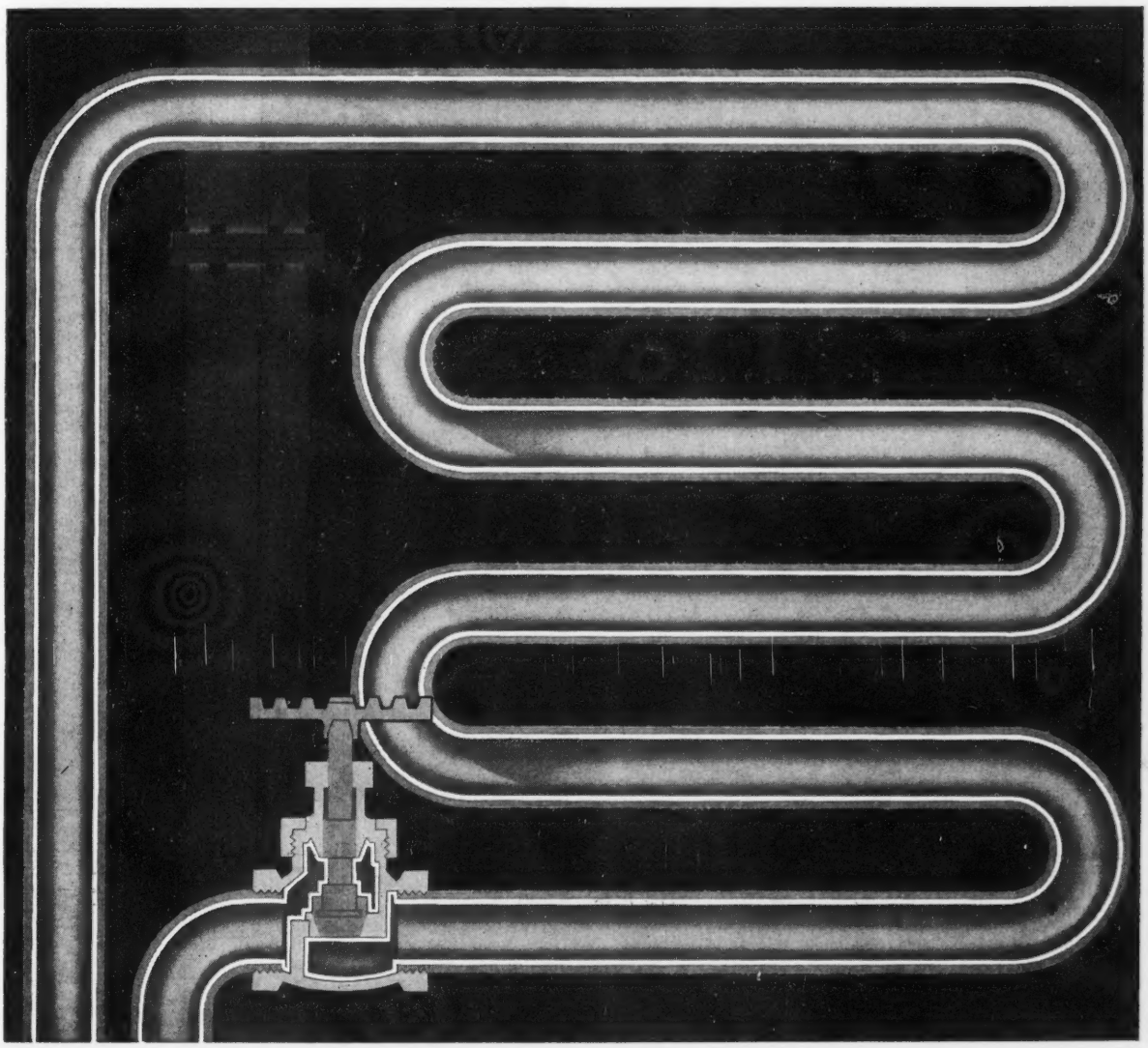
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accompanied at higher inhibitor concentrations by rise in hydrogen overvoltage. Electrode potential, inhibitive efficiency and inhibitor concentration are related in adsorption equation which is applicable to compounds adsorbed in single and fixed molecular orientation. Graphs, 35 references.—INCO. 11615

5.9 Surface Treatment

5.9.1, 5.4.7

Preliminary Surface Treatment and Lacquering of Sheet Metal in the Industrial Processing of Sheet Metal. H. ANDERS. *Metalloberflache*, **9**, No. 8, 116-118 (1955).

An account of different methods of cleaning sheet-metal surfaces by mechanical and chemical means and of applying protective lacquer coatings before shaping the sheet metal into containers. 6 references.—BTR. 11722

5.9.2

Evaluation of Metal Cleaners and Cleaning Methods. P. C. HARRIS, W. STERICKER AND S. SPRING. *Electroplating & Metal Finishing*, **8**, 423-425 (1955) Dec.

This paper summarizes and comments on methods which have been developed for the laboratory evaluation of metal cleaners and cleaning procedures under as near as possible production conditions. Fifteen tests are summarized and full literature references are given.—EL. 11520

5.9.2

Pickling Processes Reviewed. Part IV. Treating Heat-Resistant and Corrosion-Resistant Metals. D. J. FISHLOCK. *Product Finishing*, **9**, 84-97 (1956) Feb.

Discussion of methods for pickling 18/8, 12/12 and other stainless steels, heat-resisting alloys containing up to 65% nickel, Monel, "K" Monel, "S" Monel, Inconel, Nimonic 75 and F, Nichrome, Nichrome V and titanium. Sodium hydroxide baths, sodium hydride descaling and Virgo salt bath are included.—INCO. 11588

5.9.2

The Sodium Hydride Process for Descaling Metals. N. L. EVANS. *Corrosion Technology*, **3**, No. 2, 47-51 (1956) Feb.

Non-electrolytic sodium hydride descaling process, its advantages and various applications. Process plant, hydride generator, screens, sludge trays, heating methods, ventilation system and precautions in handling sodium are described. Bath used contains 1-2% sodium hydride in molten sodium hydroxide, process is operated at 350-370 C and depends on powerful reducing reaction of hydride on metallic oxides. Process is applicable to all grades of stainless steels, highly alloyed steels, constructional steels, nickel and copper and their alloys, brass, bronze and aluminum and special uses include descaling of billets to reveal surface defects and treatment of castings to remove traces of sand.—INCO. 11581

5.9.3

Barrel Finishing: A Precision Tool. W. P. NUNN. *Plating*, **43**, No. 1, 60-63 (1956) Jan.

Discusses the selection of media (stone, limestone, granite, natural bonded aluminum oxide and ceramic bonded aluminum oxide chips), selection of surface treatment compounds, use of water and the types of parts that can be barrel finished. —INCO. 11624

5.9.4

Influence of Pre-Treatment Prior to Phosphating of Steel. S. SPRING AND J. C. LUM. *Org. Finishing*, **17**, 5-9 (1956) February.

Three characteristics of zinc phosphate coatings were evaluated in an attempt to determine the effectiveness of the various recommended pre-treatments; crystal size, coating weight and porosity. Photographs, table, graph. 4 references. —BTR. 11670

5.9.4

Hard Anodizing of Aluminium and Its Alloys. F. SACCHI. *Alluminio*, **24**, No. 1, 5-15 (1955).

Sacchi describes the Kein process, Martin Hard Coating (MHC), the Savage-Sampson method and the Hardas method, all processes for hard anodizing aluminum alloys, based on the use of a sulfuric acid bath at approximately 0 C. In the course of a limited series of experiments at the Istituto Sperimentale dei Metalli Leggeri using the simplest (Savage-Sampson) method, but introducing carbon dioxide into the 10% sulfuric acid bath and with modified current density, it was shown that such coatings have an abrasion-resistance similar to that of hard chromium plate or a cyanide case. On the other hand, the fatigue strength is reduced by between 20 and 60%, according to the type of alloy. Other properties remain the same or are slightly improved. 99.5% pure aluminum gives the best results. Aluminum alloy 24S was the least suitable, while very satisfactory results were obtained with 75S. In the refrigerated sulfuric acid electrolyte very high current density and short anodizing time appeared to give best results. It would be of great interest to study the process in much greater detail in order to see whether the same results might not, somehow, be obtained at room temperature. 9 references.—MA. 11567

5.9.4

Surface Contamination of Copper by Phosphate Ion During Electropolishing: Use of P^{32}. N. H. SIMPSON AND N. HACKERMAN. *J. Electrochem. Soc.*, **102**, No. 11, 660-661 (1955) November.

Some phosphate was retained even after thorough rinsing but the amount decreased with increasing wash temperature.—BNF. 11536

5.9.4

A Review of Some Factors Influencing Nitriding Practice. G. J. COX. *J. Birmingham Met. Soc.*, **35**, 187-212 (1955) June; *Metal Progress*, **69**, No. 2, 112, 114, 116 (1956) Feb.

In thirty years of nitriding in the U. S. considerable research has been directed toward more complete understanding of process and details of temperature effect, percentage of ammonia dissociation, pressure, surface conditions, prior heat-treatment, cooling rates and denitriding. These factors are considered. —INCO. 11586

5.9.4, 6.4.2

Brightening and Anodizing Aluminium and Its Alloys. (In German.) J. HERENGUEL. *Metall*, **10**, No. 3/4, 99-103 (1956) Feb.

It is pointed out that anodizing, according to the purpose of the process, can be subdivided into four groups: Anodizing for corrosion-protection, for industrial purposes,, for decorative purposes and for brightening. The behavior of various aluminum alloys with respect to these four treatments is investigated and hence the right process for the right alloy determined. The various industrial anodizing treatments are briefly reviewed and the effects of the parameters time, temperature, current density and eletrolytic concentration are discussed. Some examples of defects occurring in anodized aluminum products are given.—ALL. 11631

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.5, 3.7.2

Rare Earth Stainless Steels. H. O. BEAVER AND B. T. LANPHIER. *Materials & Methods*, **43**, No. 2, 96-98 (1956) Feb.

Addition of Misch-metal to highly alloyed stainless steels gives improved hot workability, which results in improved yields in processing and improved resistance to corrosion in sulfuric acid. Misch-metal added to 21-12N enabled commercial production and easy forging of the alloy. Mechanical properties in austenitic stainless steels are improved. Graphs, tables, photographs.—INCO. 11573

6.2.5, 3.7.2

Effects of Niobium and Titanium on the Properties of Stainless Steel. (In Russian.) A. M. SAMARIN AND A. A. YUSKEVICH. *Bull. Acad. Sci. URSS*, Technical Sciences Section (Izvest. Akad. Nauk SSSR), No. 10, 107-116 (1955) Oct.

Experiments with various steels proved that niobium is more effective than titanium in increasing steel resistance to intercrystalline corrosion. Niobium improves the welding properties of steel and the wear resistance of tempered steel to acid.—NSA. 11532

6.2.5, 3.7.3, 3.2.2

Precipitation Processes in Titanium-Stabilized Austenitic Nickel-Chromium Steel and Their Relation to Intercrystalline Corrosion Phenomena. K. BUNGARDT AND G. LENNARTZ. *Arch. Eisenhuttenw.*, **27**, 127-133 (1956) Feb.

Analytical and x-ray investigations on titanium-stabilized 17.5 chromium-10.4 nickel steel to determine influence of quenching temperature and time at quenching temperature on precipitation phenomena during subsequent heat-treatment between 500-800 C. Correlation of tendency for grain disintegration with results of boiling copper sulfate-sulfuric acid test, theoretical explanation of formation of δ-phase observed and results readily interpreted by applying chromium depletion theory of intercrystalline corrosion are given.—INCO. 11594

6.2.5, 3.8.2, 4.3.2

Electrochemistry of Stainless Steel in Sulphuric Acid. G. H. CARTLEDGE. Oak Ridge Nat'l. Lab. *Nature*, **177**, No. 4500, 181-182 (1956) January 28.

A Type 347 steel was heated in air at 445 C for two hours and then placed in an aerated 0.1 N mixture of sulfuric acid and sodium sulfate with 1.46 pH. At the completion of the passive phase very active metal was exposed and the potential fell to its low. From its minimum value the potential rose slightly while corrosion proceeded rapidly. What fol-

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lowed next was dependent upon a combination of factors which include the corrosion resistance of the specimen, the acidity, the temperature, the partial pressure of the oxygen and the geometry of the system with respect to the availability of oxygen at the interface. Ennobling was spontaneous and artificially induced. When the sample passed the critical recovery potential, corrosion dropped suddenly to a very low value. Experiments confirm that 18-8 has a maximum corrosion rate in 20% sulfuric acid at 25 C when held at a potential of about —250 mV. Therefore the maximum corrosion-rate should occur when the depolarization by oxygen or by an applied potential is as nearly complete as it can be without raising the electrode to the hydrogen potential.—INCO. 11591

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.3, 3.8.4

Thermodynamics of the Oxidation of Chromium. J. N. Ramsey, D. Caplan and A. A. Burr. *J. Electrochem. Soc.*, **103,** 135-138 (1956) Feb.

Microbalance technique is used to determine dissociation pressure of chromium oxide over 598-1154 C temperature range. Free energy and enthalpy of oxide formation is calculated. Graph, tables, diagram. 27 references.—BTR. 11616

6.3.6, 3.2.3, 3.4.8

Mechanism of Reaction Diffusion in the Reaction of Solid Copper with Some Gaseous Elements. (In Russian.) V. I. Arkharov and S. Mardeshev. *Doklady Akad Nauk SSSR,* **103,** No. 2, 273-276 (1955) July 11.

Reaction of copper with iodine, bromine, chlorine, oxygen, sulfur, selenium, tellurium, phosphorus, silicon and zinc; nature of products and their orientation and adherence to the metal; mechanisms of the various reactions. Partly based on authors' previous work.—BNF. 11724

6.3.6, 3.8.4, 4.3.2

The Kinetics of the Corrosion of Copper in Acid Solutions. John Randel Weeks and George Richard Hill. *J. Electrochem. Soc.*, **103,** No. 4, 203-208 (1956) April.

The mechanism of the initial corrosion of copper in hydrochloric acid solutions has been investigated, using a radioactive tracer technique. Kinetic data have been obtained showing the effect of pH, dissolved oxygen, chloride ion and temperature on the corrosion rate. Surface areas were measured using a modified electrolytic method. On the basis of these data (reproducible to ±20%), a mechanism for the initial corrosion process is proposed and discussed. Specific rate constants, heats and entropies of activation for the slow step in the corrosion process were determined. 11649

6.3.6, 6.4.2

Nature of Plastic Deformations of the Surface Layers of Rubbing Bodies. (In Russian.) K. V. Savitskii and M. P. Zagrebennikova. *Doklady Akad. Nauk SSSR,* **103,** No. 4, 605-608 (1955) August 1; errata *ibid.*, **103,** No. 5, 746 (1955) August 11.

Effect of compression and friction on the microhardness of copper and aluminum; also of annealing temperature on the microhardness and temperature coefficients of microhardness and relaxation. Behavior of surface layers during friction is discussed.—BNF. 11570

6.3.9, 3.7.2

Search for Oxidation-Resistant Alloys of Molybdenum. G. W. P. Rengstorff. Paper before Am. Inst. Mining Met. Engrs., Philadelphia, October, 1955. *J. Metals* (Trans. AIME), **8,** No. 2, 171-176 (1956) Feb.

Binary and ternary alloys of molybdenum with aluminum, chromium, cobalt, iron, nickel, silicon, titanium, tungsten, vanadium and zirconium were screened for oxidation-resistance. Tests were made from gradient-composition ingots. Actual oxidation tests consisted of heating ingots with control sample of molybdenum, on insulating brick in a nickel-lined steel tube for four hours at 1800 F. Effects of boron, boron-iron, platinum, copper, lead, thorium, beryllium, tin, antimony, manganese, lithium, magnesium, zinc, silver and cadmium were also studied. Further tests at 1800 and 2000 F were made on more oxidation-resistant alloys, including 15 nickel-molybdenum and 13 nickel-2 cobalt-molybdenum. At least 15 nickel or 25 chromium is required to reduce oxidation rate of molybdenum by factor of 100. This does not begin to approach required oxidation resistance at high temperatures. Reduction of oxidation rate by nickel is due to formation of nickel molybdate. Graphs, tables.—INCO. 11617

6.3.11, 3.2.3, 3.8.4, 2.3.7

Selective Oxidation of Silver-Magnesium Alloys in Water Vapor. (In English.) Masaki Hirashima. *J. Phys. Soc. Japan,* **10,** No. 12, 1055-1064 (1955) Dec.

Simple method for measuring low rates of oxidation at elevated temperatures with water vapor used as oxidizing agent. It is found that the magnesium oxide layer builds up on the surface of the alloy according to a parabolic law and the oxide growth begins to follow a linear law rather than a parabolic law at a pressure of 1 mm Hg. Diagrams, micrographs, graphs, table. 22 references.—BTR. 11518

6.3.11, 3.8.4, 3.2.3

Enhanced Oxidation of Platinum in Activated Oxygen. George C. Fryburg. *J. Chem. Phys.*, **24,** 175-180 (1956) Feb.

An enhanced oxidation of platinum was observed in moist activated oxygen. Cause of this enhancement investigated. Diagrams, graphs, tables. 17 references. —MR. 11618

6.3.11, 6.3.6

Silver-Palladium-Copper Alloys (and System). Ernst Raub and Georg Worwag. *Z. Metallkunde,* **46,** No. 1. 52-57 (1955).

Ternary alloys containing silver 3-80, palladium 10-65 and copper 5-50 wt.-% were prepared by melting the high purity components in a hydrogen atmosphere. After a homogenizing anneal, they were examined by X-ray-diffraction techniques and by thermal and metallographic analysis. The results are used to construct a temperature/concentration section for the PdCu-Ag region, and isothermal sections of the ternary diagram at 600 and 400 C. In the ternary system, the PdCu transformation becomes a true phase transformation; introduction of silver into the PdCu lattice does not suppress the PdCu transformation so long as the palladium:copper ratio is correct, but the silver raises the formation temperature of the PdCu, although it has little effect on the lattice constant. The maximum solubility of silver in PdCu is 3.5, 4.0 and 6.0 at.-% (4.5, 5.2 and 7.2 wt.-%) at 400, 500, and 600 C, respectively. Supersaturated alloys do not show the PdCu transformation. The miscibility gap in the solid state found in the silver-copper binary system is divided into five regions in the ternary system as a result of the formation of PdCu, viz. two outer ($\alpha_1 + \alpha_3$) solid-solution regions (α_1 is the silver-rich, α_3 the copper-rich solid solution), bordering two ($\alpha_1 + \alpha_2 +$ PdCu) regions which are separated by a central ($\alpha_2 +$ PdCu) region. The corrosion-resistance and the precipitation hardening of the alloys are discussed. Precipitation-hardening is generally carried out between 300 and 500 C and, if it is excessive, can lead to brittleness and incipent cracking, which, if not noticed, can lead to erroneous deductions in regard to stress-corrosion. 6 references.—MA. 11540

6.3.15, 1.6

Titanium. A. D. McQuillan and M. K. McQuillan. Book, 1956, 466 pp. Butterworths Scientific Publications, London; Academic Press, New York.

History of the metal, occurrence of its ores, extraction and purification; melting, casting and fabrication, including joining and machining; physical properties, alloy systems, deformation mechanisms and textures, the α-β transformation and its mechanism; heat treatment and mechanical properties of pure and commercial titanium and of commercial and other alloys; case-hardening; corrosion and reactions with gases; and finally metallographic techniques are covered.

The picture which emerges is of a metal which behaves logically and consistently and which on the technical side can be readily understood. However, more about what should not be done in the ordinary handling of the metal could have been included.—BNF. 11611

6.3.15, 3.2.2

Hydrogen Embrittlement of Titanium Alloys. H. M. Burte and others. *Metal Progress,* **67,** No. 5, 115-120 (1955) May.

Investigation at Wright Air Development Center of premature failure of titanium aircraft engine parts. Results of room temperature tensile tests on Ti-140A alloy are analyzed. Effects of hydrogen on rupture properties of flat sheet specimens were found to be essentially same as those observed for cylindrical specimens from bar stock. Effect of heat treatment given. Hydrogen level at which embrittlement becomes noticeable depends upon alloy composition and heat treatment.—BL. 11706

6.3.15, 3.6.6, 4.4.2

Galvanic Corrosion Properites of Titanium in Organic Acids. David Schlain, Charles B. Kenahan and Doris V. Steele. U. S. Bureau of Mines, Report of Investigations 5189, January, 1956, 17 pp.

Acids used were 10% formic, acetic, lactic and citric, 1% oxalic and tartaric and 9% oxalic. Electrode-potential measurements and several types of galvanic couple experiments were carried out. Solutions were aerated by flow of air, flow of helium and natural aeration, at 35 C with couples consisting of equal areas of two metals. Tables, graphs, diagrams. 8 references.—MR. 11604

6.3.15, 3.8.2

Equilibrium Potential/pH Diagram for the System Titanium-Water: Corrosion of Titanium. J. Schmets and M. Pourbaix. Proc. 6th Meeting Internat. Cttee. Electrochem. Thermodynamics and Kinetics (Poitiers, 1954), 1955, 167-179.

Calculations are made of the equilibrium between titanium, TiO, Ti_2O_3, $Ti(OH)_3$, Ti_3O_5, TiO_2 hydrated, rutile, water and the aqueous ions, H^+, Ti^{3+}, Ti^{3+}, TiO^{2+}, $HTiO_2^-$ and TiO_2^{2+} at 25 C

and are represented in diagrams of electrode potential/pH. The corrosion of titanium is considered in the light of these diagrams. 29 references.—MA. 11539

6.3.15, 4.3.2, 5.8.3

Effect of Fluorides and Other Addition Agents on the Cathodic Potential of Titanium in Hydrofluoric Acid. M. E. STRAUMANIS, S. T. SHIH AND A. W. SCHLECHTEN. *J. Electrochem, Soc.*, **102,** No. 10, 573-576 (1955) October.

The absolute hydrogen overvoltage values of titanium in hydrofluoric acid increase, or the cathodic potentials, η_H, decrease (become more negative) with addition of alkali fluorides to the acid. The η_H decreases with increasing concentration of the salt in the sequence ammonium fluoride→ potassium fluoride→ sodium fluoride, which is also the sequence of decreasing cationic radius. For example, at 50 ma/cm² η_H decreases from —0.8 v in pure 0.1 N hydrofluoric acid to —1.68 v in the same acid if it is 1 M with respect to sodium fluoride. If the titanium cathode dissolves in the acid, the η_H—current density relationship is linear; if the dissolution ceases (at higher concentrations of the added fluoride), Tafel's relationship is fulfilled. In between there is a mixed straight line and quasi logarithmic relationship, the latter occurring at higher current densities. Organic colloid solutions of agar-agar or arabic gum appreciably decrease η_H; methylene blue solutions increase it slightly. (auth). —NSA. 11557

6.3.16, 3.8.4, 3.5.9

Oxidation of Tungsten. WATT W. WEBB, JOHN T. NORTON AND CARL WAGNER *J. Electrochem. Soc.*, **103,** 107-111 (1956) Feb.

Investigation in the 700 to 1000 C range, covering wide time span, shows that oxidation initially follows the parabolic law, eventually changing to the linear. An over-all rate equation is calculated. Micrographs, table, graphs. 20 references.—BTR. 11660

6.3.20, 3.7.3

Zirconium: Fabrication Techniques and Alloy Development. C. E. LACY AND J. H. KEELER. Paper before Am. Soc. Mech. Engrs., Spring Meeting, Baltimore, April 18-21, 1955. *Trans. ASME*, **78,** No. 2, 427-433 (1956) Feb.

Fabrication techniques, including heat treatment, hot-working, cold fabrication, machining and welding and brazing, neutron-absorption characteristics, mechanical properties and corrosion resistance of zirconium and zirconium alloys. Mechanical properties are tabulated for Zircaloy-2, an alloy containing tin, iron, nickel and chromium. Tables, graphs, 25 references.—INCO. 11623

6.3.20, 4.6.1

Zirconium Progress Report for the Period March 15-June 15, 1955. Northwest Electrodevelopment Experiment Station, Albany, Ore. U. S. Bureau of Mines Publication, Contract AT-(11-1)-140, July 28, 1955 (changed from Official Use Only October 26, 1955), 44 pp.

The results of 155 Kroll process reduction runs using lined reduction crucibles are summarized. There was no noticeable difference in the oxygen content of zirconium sponge prepared with purified magnesium or changes in the air exposure conditioning techniques. Further investigations on treatment of Zircaloy 2 scrap indicate that under proper conditions, molten calcium appears to be more effective than vaporous calcium as a deoxidant. The present status of studies involving the mechanism of metallic arc is presented. Hot water corrosion data show that hafnium-titanium alloys containing over 50 wt.% titanium have decreasing corrosion resistance. First results of heat treated zirconium-titanium and zirconium-iron alloys are shown. (auth).—NSA. 11699

6.3 20, 4.6.1, 3.2.3

Identification and Growth of Oxide Films on Zirconium in High-Temperature Water. C. M. SCHWARTZ, D. A. VAUGHAN AND G. G. COCKS. Battelle Memorial Institute. U. S. Atomic Energy Comm. Pubn., BMI-793, December 17, 1952 (Declassified October 18, 1955), 46 pp.

This report presents a summary of a series of observations concerning oxide formation on zirconium and zirconium-tin alloys in 600 F water. The progress of corrosion has been followed microscopically and by electron and x-ray diffraction. Three stages in the progress of corrosion can be described: the formation of a thin tetragonal oxide film coherent on the base metal, the transformation of the tetragonal to the monoclinic oxide, which grows at an accelerated rate but retains coherency with the substrate and failure by loss of coherency of the oxide and formation of white oxide. In the second stage, differences in the local charcter of corrosion were observed between good and bad zirconium. Two hypotheses have been proposed to account for the differences in corrosion rates of zirconium. (auth).—NSA. 11537

6.3.20, 6.3.21, 4.6.1

Zirconium Progress Report for the Period of June 15-September 15, 1955. Northwest Electrodevelopment Experiment Station, Albany, Ore. U. S. Bureau of Mines Publication, Contract AT-(11-1)-140, October 10, 1955 (changed from Official Use Only October 26, 1955), 41 pp.

Studies were continued on the production of hafnium and low-oxygen zirconium. The feasibility of casting zirconium was investigated. Hot water corrosion data are presented for zirconium, hafnium, zirconium-tin, titanium-zirconium, iron-zirconium and hafnium-titanium alloys. —NSA. 11716

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 2.3.7

Tensile Properties of 7075-T6 and 2024-T3 Aluminum Alloy Sheet Heated at Uniform Temperature Rates Under Constant Load. G. J. HEIMERL AND J. E. INGE. NACA Tech. Note 3462, July, 1955, 46 pp.

Results of tests to determine effect of heating at a uniform rate (0.1 to 55 C per sec.) on tensile properties of 7075-T6 (aluminum-5.6 zinc-2.5 magnesium-1.6 copper-0.3 chromium-0.2 manganese) and 2024-T3 (aluminum-4.5 copper-1.5 magnesium-0.6 manganese) under constant load. Yield and rupture temperatures for different stress levels and comparison with results of elevated temperature stress-strain tests for ½ hr. exposure. Description of testing equipment and procedure. —BNF. 11544

6.4.2, 3.5.8

On the Corrosion-Fatigue Properties of Aluminum Alloys in a 3% Sodium Chloride Aqueous Solution. K. TAKEUCHI. *Sumitomo Metals*, **8,** No. 1, 24-31 (1956) Jan.

Results of study of corrosion-fatigue properties of aluminum alloy in a 3% sodium chloride aqueous solution with Ono's rotary bending machine. Endurance strength of aluminum alloys was much reduced. Resistance to corrosion-fatigue in the case of aluminum-magnesium alloy increased with magnesium content and in the case of aluminum-Mg_2Si alloy increased with Mg_2Si content. Fatigue strength was not influenced by cold-working and heat-treatment at 10,000,000 cycles and high strength aluminum alloys of 17S, 24S and 75S were superior to the corrosion-resistant aluminum alloys at 10,000,000 cycles. Illustrations.—INCO. 11639

6.4.2, 3.5.8

The Interaction of Static Stress and Corrosion with Aluminium Alloys. F. A. CHAMPION. *Metallurgia*, **53,** No. 316, 63-68 (1956) Feb.

Review of information available on stress corrosion of aluminum alloys (including the various grades of pure aluminum). Term stress corrosion as used in this paper implies a greater deterioration in the mechanical properties of the material through the simultaneous action of a static stress and exposure to corrosive environment than would occur by the separate, but additive, action of those agencies. Mechanism of failure, environment, stress conditions, composition and condition of alloy and protective measures are discussed. Standard British wrought aluminum alloys not

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significantly susceptible to stress corrosion and those not normally requiring protection against stress corrosion are tabulated. H.12 (2.25 copper, 1.5 nickel, 1 magnesium, 1 iron) is highly susceptible. Rolled on aluminum cladding and sprayed aluminum coatings offer maximum protection. Graphs, photomicrographs, 27 references.—INCO. 11593

6.4.2, 3.6.6

Aluminium in Contact with Other Materials. Aluminum Development Association, Information Bulletin No. 21, December, 1955, 48 pp. Available from: ADA, 33 Grosvenor St., London, W 1.

Aluminum as material of construction; corrosive attack on metals; practical means of preventing corrosion; aluminum contact with specific metallic and non-metallic materials with an approximate guide to bimetallic effects; practical applications of preventive methods in various branches of engineering.—BNF. 11723

6.4.2, 3.7.3

Aluminium Structures. (In German.) FRITZ STUSSI. Book, 1955, 198 pp. Springer-Verlag, Berlin/Gottingen/Heidelberg, Germany.

Following a general survey of aluminum as a structural material and of its properties, the various methods of joining, such as riveting, bolting, welding and bonding are discussed. It is stated that problems of strength and stability, when dealing with aluminum structures, need an approach fundamentally different from the conventional way of "thinking in terms of statics." Accordingly, stress and strain problems related to structural aluminum components are treated in detail. Methods of fabrication and assembly, also surface treatment and corrosion protection are discussed. Several outstanding examples of structural applications of aluminum, such as bridges, hangers, transmission line towers, avalanche fences, silos and dredge clamshell buckets are presented. As a conclusion, a synopsis of standards and technical data of wrought aluminum alloys is given.—ALL. 11569

6.4.2, 3.7.4, 3.7.2

Structural Evolution of Ageing of Aluminium-7% Magnesium Alloys and the Effect of Mg_2Si on the Sensitizing to Intercrystalline Corrosion. (In French.) ADRIEN SAULNIER. *Rev. Aluminium*, **32**, No. 226, 1011-1014 (1955) November.

During the ageing at 200 C of a superpurity aluminum-magnesium 7% alloy, there appears, as well in the boundaries as inside the grains, very minute particles of Al_3Mg_2 phase which, during the first hours of ageing, can be observed only with an electronic microscope. These particles are surrounded by matrix rings having a low magnesium content. These rings can be made visible in optical micrography by a special etch (Buckle, Changarnier and Calvet reagent). When the particles at the boundaries are in sufficient numbers, the rings can merge forming a practically continuous streak of low content matrix. In common grade alloys, the precipitation process of Al_3Mg_2 is the same. But, silicon, the impurity in the aluminum base metal, plays a fundamental part: When the homogenization temperature is reached, it passes into solution and afterwards precipitates as Mg_2Si by ageing, provoking a structural hardening effect which is most notable with the low magnesium content. Furthermore, the sensitizing to intercrystalline corrosion of the commercial grade alloys is also related to the presence at the grain boundaries of a film of Mg_2Si constituent. (auth.)—ALL. 11521

6.4.2, 3.8.4, 3.5.9

Oxidation of Aluminum in the Temperature Range 400-600 C. W. W. SMELTZER. *J. Electrochem. Soc.*, **103**, No. 4, 209-214 (1956) April.

The surface oxidation kinetics of metallographically polished high purity aluminum were studied in the temperature range 400-600 C using a vacuum microbalance technique. The oxidation rate of aluminum decreased to a low value after a formative stage of film growth which was governed by a parabolic law. Values of the activation energies of reaction were determined from the temperature coefficient of the parabolic law constants and were compared with other values reported in the literature. By attaching equal significance to gaseous and anodic oxidation results, a value of 37.2 kcal/mole (1.6 ev) was determined for the potential energy barrier against ion diffusion at the metal/oxide interface. 11655

6.4.3, 5.3.4

Plating and Cladding of Beryllium. J. T. STACY. Paper from "The Metal Beryllium" (Am. Soc. Metals), 1955, 295-303.

Details are given of the procedure and bath composition for the plating of beryllium with a variety of metals in order to enhance its corrosion-resistance. The metals listed are aluminum, cadmium, chromium, copper, gold, indium, iron, nickel, silver, tin and zinc. Cladding with aluminum can be carried out by rolling or dipping and with nickel by the carbonyl process. Surface treatments for beryllium are noted. 12 references.—MA. 11572.

6.4.2, 5.8.2, 4.4.3

Corrosion Testing of Aluminum. Part II. Development of a Corrosion Inhibitor. SUMNER B. TWISS AND JACK D. GUTTENPLAN. *Corrosion*, **12**, No. 7, 311t-316t (1956) July.

An accelerated corrosion test was used to test a number of corrosion inhibitors at different concentrations to determine their effectiveness in preventing corrosion of No. 100 aluminum brazing sheet in Royal Oak tap water. Four inhibitors were found to be effective under conditions of static test, 1000 rpm and 12,000 rpm. These inhibitors were: Soluble oil with or without trisodium phosphate, sodium dichromate, sodium silicate and disodium hydrogen phosphate. Of these, all but the soluble oil are either noncompatible or might lose their effectiveness when used in standard antifreeze solutions. The corrosion inhibition of clad aluminum by soluble oil is less effective in waters of combined high pH and high chloride ion than it is in waters of high chloride alone. Addition of a buffer to the soluble oil to maintain the solution pH near 7.0 improves the effectiveness of this inhibitor in high pH solutions. The combination of soluble oil and buffer satisfactorily inhibits the corrosion of clad aluminum in 1:1 ratio ethylene glycol-water (pH 11) and isopropyl alcohol-water (pH 11) solutions, typical of the worst radiator solutions that might be encountered. The inhibition is somewhat less effective when the clad aluminum is coupled with brass. 11675

6.6 Non-Metallic Materials

6.6.1, 1.6, 1.5

Corrosion Resistance of Non-Metallic Materials. (In German.) FRANZ RITTER. Book, 1956, 232 pp. Springer-Verlag, Vienna, Austria.

Resistance of numerous synthetic and natural non-metallic materials are tabulated under an alphabetical listing of corrosives. Temperature limits are indicated. 1164

6.6.8, 3.5.9, 2.3.7

Methods of Study of High-Temperature Properties of Plastics. W. F. BARTON. *Modern Plastics*, **33**, No. 1, 151-152, 154, 156, 242, 244 (1955) Sept.

Study of thermal degradation resistance, dimensional stability and useful strength are discussed. Results are given of methods used for comparatively evaluating materials.—BL. 1169

6.6.8, 7.2

How Plastic Pipe Is Used in Our Mills. D. T. SKOWLUND. B. F. GOODRICH Co. *Paper Trade J.*, **140**, No. 8, 38-40 (1956) Feb. 20.

Discusses application of plastic pipe with case histories of experiences in six mills. Survey shows that plastic pipe is vying with steel and stainless steel to handle white water, caustic soda, sulfuric acids, alum solution, calcium hypochlorite, sodium hypochlorite, chlorine dioxide and fresh water. Table gives recommended working pressures for rigid Koroseal pipe.—INCO. 11673

6.7 Duplex Materials

6.7.2

Oxidation Studies in Metal-Carbon Systems. WATT W. WEBB, JOHN T. NORTON AND CARL WAGNER. *J. Electrochem. Soc.*, **103**, 112-117 (1956) Feb.

General analysis of oxidation characteristics of alloys containing carbon or carbides. Data on nickel, tungsten, manganese and titanium-carbon systems. Graphs. 21 references.—BTR. 11658

6.7.2

Fundamental Study and Equipment for Sintering and Testing of Cermet Bodies. Part VII. Fabrication, Testing and Properties of 34 Aluminum Oxide-66 Chromium-Molybdenum Cermets. THOMAS S. SHEVLIN AND CHARLES A. HAUCK. *J. Am. Ceram. Soc.*, **38**, 450-454 (1955) December.

The properties of a cermet solid body containing 34% aluminum oxide and 66% 80 chromium-20 molybdenum alloy (50 aluminum oxide-50 alloy by volume) are given as firing shrinkage, density, modulus of rupture, tensile strength, stress-rupture life, modulus of elasticity, oxidation resistance, thermal-shock resistance and thermal expansion. It is shown that substitutions of the 80 chromium-20 molybdenum alloy for chromium in a similar cermet developed earlier substantially improved thermal-shock resistance. (auth.)—NSA. 11535

6.7.2, 1.6

Fundamental Properties of Metal-Ceramics Mixtures at High Temperatures. Final Report (for) June 1, 1946-January 1, 1955. E. L. SWARTS AND W. B. CRANDALL. Alfred Univ., Alfred, N. Y., 104 pp.

A study was made to formulate from mixtures of metals and oxides new compositions for high-stress and high-temperature applications which might possess the more favorable characteristics of both classes of materials. The general problems of thermal diffusivity and shock, metal oxidation and solid state diffusion are summarized. (auth.)—NSA. 11574

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1, 3.5.3

Welding in the Maintenance and Repair of Hydro-Electric Turbines. K. C. DAVIDSON. Paper before Nat'l Welding Convention, Sydney, October, 1955. *Australasian Engr.*, **1956**, 58-60, January 7.

Covers erosion, corrosion and cavitation in Pelton turbines (impulse type) and Francis turbines (reaction type), service conditions, weak points and areas of attack. Relative pitting resistance due to cavitation is tabulated for turbine runner materials—welded, cast and rolled 18-8, cast 14 chromium-1 nickel stainless steel, 0.33 carbon steel, manganese-bronze and cast iron. Repair welding of cracks in Pelton turbine bucket with mild steel electrodes and building up needle of Pelton turbine with 18-8 electrodes are described.—INCO. 11587

7.4 Heat Exchangers

7.4.2

Water Impingement Attack on Steam Sides of Condenser Tubes. C. B. TULEY. *Bur. Ships J.*, **4**, No. 10, 21 (1956) Feb.

Corrosion of the steam side of condenser tubes caused by impingement of water droplets on the tubes is prevented by the installation of a stainless steel shield which is formed to snap onto the tube.—INCO. 11668

7.4.2, 4.6.2, 6.3.6

High-Quality Gasoline and Diesel Fuel from Wyoming Black Oils. F. B. ODASZ AND J. V. SHEFFIELD. Husky Oil Co. *Oil Gas J.*, **54**, No. 38, 64-66 (1956) January 23.

After two years of operation of Catformer-Diesulformer, it was found that finned-tube sections of water cooler were badly corroded due to ammonia formed by reaction of nitrogen in feed with recycle hydrogen. Tubes were originally of Admiralty and were replaced with steel tubes.—INCO. 11626

7.5 Containers

7.5.2, 8.3.2, 2.3.7

Beverage Can Linings. E. S. BECK. *Org. Finishing*, **16**, No. 11, 13-20 (1955).

A description of the coatings employed in flat and cone top beer and soft drink cans. The shelf life expectancy of cone top cans may be 100% greater than that of the flat top containers. Tin plate stock is used exclusively, a hot dip process being employed in place of electrolytic tin plate where severe corrosion is anticipated. Standard linings consist of two coats which are applied by roller: a base coat of either a modified phenolic varnish or epoxy phenolic coating, followed by a vinyl resin coating for flat top cans, or, in the case of cone top cans, a base coat of micro-crystalline wax followed by a tung oil/phenolic varnish. Methods of testing film continuity and ability to withstand internal pressure are described.—RPI. 11689

7.5.5, 5.2.2, 1.2.2

Cathodic Tank Protection—5 Years Later. R. D. YINGLING. Gulf Oil Corp. *Oil Gas J.*, **54**, No. 42, 113-114 (1956) Feb. 20.

Discusses mechanism of galvanic corrosion, life of magnesium anodes and details of anode installation and external circuits. Average life of steel tanks handling corrosive brines was 5.2 years with expense due to corrosion damage averaging $24.50 per month per tank; cathodic protection costs $1.50-$2.50 per month. In 4½ years with cathodic protection, only 1 out of 36 tanks required replacement.—INCO. 11666

7.7 Electrical—Telephone and Radio

7.7, 5.2.1

Cathodic Protection of Lead Sheathed Cables in the Utilities Industry. Technical Unit Committee T-4B on Corrosion of Cable Sheaths. I. C. DIETZE, chairman. (Prepared by Task Group T-4B-2 on Cathodic Protection of Cable Sheaths. R. M. Lawall, chairman and J. J. Pokorny, vice-chairman.) *Corrosion*, **12**, No. 7, 355t-370t (1956) July.

Replies to two questionnaires concerning lead and copper-jacketed cables are summarized. Seventeen power companies, 10 communication companies and one electrolysis committee sent replies.

Cathodic Protection Criteria: Negative potentials used ranged from .05 to 0.5 volt negative, with some preference for 0.2 to 0.3 volt negative. Currents used to protect steel tape or wire armored cable were in the vicinity of 0.85 volt negative to a copper-copper sulfate electrode near the cable. On copper-jacketed cable a potential of 0.1 to 0.25 volt negative is used.

Ground Bed Design and Location: Scrap steel, iron and cable are used either in point or distributed beds. Some inert anodes are used in point beds and a few installations of magnesium galvanic anodes are reported.

Power Source: Selenium rectifiers are preferred but other kinds, including vacuum tube types are reported on.

Protection Coordination: Most users of rectifiers report some kind of protection coordination among plant operators.

Interference Filters: Used to prevent noise on telephone circuits.

Surge and Lightning Protection: Some operators provide means of grounding surges or lightning charges.

Insulating Joints: Some use is reported, especially on cables entering office buildings, between aerial and underground cables and in stray current areas. Numerous uses for insulating joints on power cables are reported.

Protective Coatings: Some use is reported and no user reports damage from cathodic protection currents. 11682

8. INDUSTRIES

8.2 Group 2

8.2.2, 8.4.5

Sodium Graphite Reactor 75,000 Electrical Kilowatt Power Plant. C. STARR. Paper before International Conf. on the Peaceful Uses of Atomic Energy, Geneva, August, 1955. United Nations Paper A/CONF. 8/P/493, July 20, 1955, 42 pp.; Fluid Handling, No. 70, 321-322, 324 (1955) November.

Description of Sodium Graphite Reactor (SGR) system. Advantage of sodium coolant is absence of chemical corrosion in metal systems. Wide variety of steels and other alloys may be utilized as construction materials. Reactor core consists of an array of closely packed, hexagonal graphite cells canned in zirconium and contained in large steel tank. Uranium fuel elements are clad with Type 304 and rods are spaced from each other

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by helically wrapped steel wires. Core tank is made from stainless steel plate. Control and safety elements operate within stainless steel thimbles, each rod being made up of a stainless steel tube surrounded by boron rings. Thermal shield is of mild steel. Foundation concrete is lined with mild steel plate. Tables, graphs, diagrams.—INCO. 11555

8.4 Group 4

8.4.3

Corrosion Control in Oil and Gas Producing Equipment. J. L. GATTENMEYER, F. W. HEWES AND W. H. SEAGER. Paper before Can. Inst. Min. & Met., Petrol. & Nat. Gas Div., Edmonton, May, 1955 *Can. Mining Met. Bull.*, **49**, No. 525, 31-36 (1956) Jan.

Causes and mechanism of corrosion and six methods of corrosion prevention are reviewed. Corrosion preventive measures as applied to gas and oil field equipment discussed include external corrosion, internal corrosion, emulsion treaters and tanks. Diagrams, photographs, table.—INCO. 11613

8.4.5

Problems in Materials for Nuclear Power. JOHN P. HOWE. Symposium on Nuclear Metallurgy (Am. Inst. Min. Met. Engrs.), 1955, 9-28.

The diverse problems associated with the materials used in nuclear reactors are discussed under the headings: Solid-fuel reactors, fluid-fuel systems, materials and processes and physical and chemical phenomena. Among the topics discussed in some detail are: Temperature distribution in coolants and fuel elements; irradiation damage and thermal cycling of uranium; effects of fission products in fuel elements; suitable cannings or coatings for elements and diffusion and corrosion in these materials; radiation effects in graphite; strength and corrosion of structural materials under irradiation; processing techniques for various types of reactor; formation of vacancies and interstitials in a variety of materials and various aspects of uranium metallurgy. 24 references.—MA. 11547

8.4.5, 4.7, 1.6

Reactor Heat Transfer Information Meeting Held at Brookhaven National Laboratory, October 18-19, 1954. Division of Engineering, AEC and Brookhaven National Lab., Upton, New York. U. S. Atomic Energy Comm. Pubn., BNL-2446, December, 1955, 195 pp.

The following unclassified papers were presented at the Reactor Heat Transfer Information Meeting in October, 1954: Heat Transfer Rates to Cross-Flowing Mercury in a Staggered Tube Bank; Specific Heat of Liquid Metal and Salt Mixtures; The Effect of Gas Entrainment on the Heat Transfer Characteristics of Liquid Mercury; Flow in a Thermal Convection Harp in the Grashof modulus Range From 10^4 to 10^6; Theoretical and Experimental Investigation of Heat Transfer by Laminar Natural Convection Between Parallel Plates; Remarks on Forced Heat Convection in Cylindrical Channels; Potential and Parabolic Velocity Distributions; High Temperature Liquids; Heat Transfer to Boiling Water Forced Through an Electrically Heated Tube; Boiling Density Studies in Multiple Rectangular Channels; Measurement and Prediction of Density Transients in a Volume-Heated Boiling System; Heat Transfer and Corrosion Tests for a Sodium-Cooled Fast Breeder Reactor; and Free Convection in Narrow Vertical Liquid Metal Annuli.—NSA. 11605

8.4.5, 8.2.2, 4.6.1

Pressurized Water Reactor as a Source of Heat for Steam Power Plants. J. M. KAY AND F. J. HUTCHINSON. Paper before Institution of Mech. Engrs., December, 1955. *Engineering*, **181**, 78-82; disc., 82-83 (1956) Jan. 20.

Illustrated description of a pressurized-water reactor design. Pressure vessel is fusion-welded mild steel. Reference was made to highly corrosive properties of high-temperature water, with particular reference to zirconium alloy, stainless steel-clad fuel elements, pressure shell metallurgy, absence of adequate technique for sound welding of stainless steel plate in United Kingdom and difficulties in use of clad steel due to stress-corrosion cracking by demineralized or deoxygenated water.—INCO. 11663

8.4.5, 8.9.5

Nuclear Power for Merchant Ships. C. H. JOHNSON AND P. V. JOHNSON. Paper before Soc. Naval Architects & Marine Engrs., Gulf Section, Dec. 2, 1955. *Marine Eng.*, **61**, Nos. 1, 2, 34-41, 67; 74-78 (1956) Jan., Feb.

Describes general characteristics of various nuclear-power plants under development and discusses possibility of each being used aboard a merchant ship. Reactor fuels, coolants and moderators are discussed. Reactors are classified as homo- and heterogeneous. Thermal and fast breeders and fast, intermediate and thermal reactors are discussed under latter classification. Described for marine application are pressurized water reactor plant, liquid-metal-cooled reactor plant, dual-cycle boiling-water reactor plant and closed-cycle boiling-water plant. Most important factor limiting temperature of coolant entering steam generator in pressurized water-cooled reactor is corrosion in the system. 2 ppm dissolved solids in system is maximum. Water leaving reactor loses its radioactivity within 5-10 minutes but corrosion products retain their activity for longer periods. Erosion and corrosion of steam turbine system are discussed.—INCO. 11595

8.9 Group 9

8.9.3

Corrosion Control Pays Off. T. L. CANFIELD. *Am. Gas J.*, **183**, 11-14 (1956) March.

In a distribution and transmission system assembled with a variety of facilities including all kinds of pipe and construction practices, the problems of providing adequate protection against corrosion are myriad. How a company is providing this protection is outlined. Drawing.—MR. 11590

8.9.5, 5.2.2, 7.5.5.

Care and Operation of Gasoline and Heat Tanks. *Bureau of Ships J.*, **4**, No. 8, 24-26 (1955) Dec.

Discusses installation of magnesium anodes inside tank to lessen corrosion. Magnesium is attacked and corroded when tank is filled with sea water, building up protective coating on steel. Protective coating keeps corrosion at minimum when tank is filled with heavy end aviation fuel or gas. Tank history reports, potentiometric testing of tank potential, installation and replacement of anodes and dangers of hydrogen formation are discussed.—INCO. 11707

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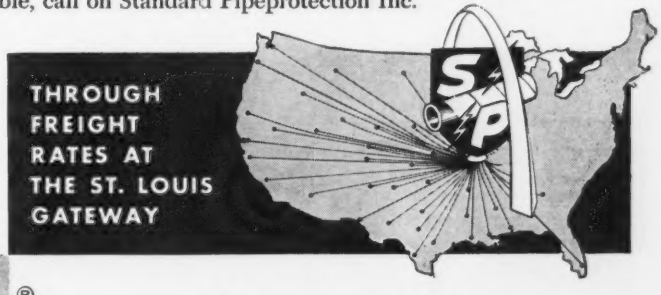
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William C. Greenleaf has been named Manager of Metals Development for U.S.I. and will be responsible for market development and sales of zirconium and titanium sponge, to be produced from U.S.I.'s two new plants now being built in Ashtabula, Ohio.

A recognized authority in the field of zirconium and titanium, Mr. Greenleaf presented three papers during the 1955 Atomic Industrial Forum Zirconium Program, describing (1) melting of zirconium, (2) fabrication of zirconium, and (3) zirconium mill products and prices. He also conceived and developed processes now in general use for producing both wide-sheet and flat-bar titanium and zirconium by continuous strip-mill techniques.

Faye Named Manager of Sodium Product Sales



Martin Faye has been named Manager of Sodium Product Sales for U.S.I. and will be responsible for coordinating sales and sales promotional activities for metallic sodium, "U.S.I. Isosebacic" acid and related products.

Mr. Faye joined the U.S.I.-National Distillers organization in 1952 in the Market Research and Development Department.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing the Editor, U.S.I. Chemical News.

A zirconium-copper alloy now available is reported to combine high electrical conductivity with good strength retention at elevated temperatures. Suggested for electrical motor commutators serving above 500°F where strength is needed. Conductivity is 95.8% of copper. **No. 1193**

Titanium wire cloth is now on the market in sizes from 60 mesh to coarser grades. It is reported to be particularly suitable for filtering or screening highly corrosive materials. **No. 1197**

Zirconium and Titanium Lick Roughest Corrosion Problems

Metals to be Available at Lower Cost in Future; Provide Long-Lived Materials of Construction; Complement Each Other on Corrosion Resistance

It is now practical to fabricate equipment which is *corrosion-resistant to almost every substance encountered in industry*, by using either zirconium or titanium metal. Alloys of either metal, or possibly both, may extend the range even further.

Industrial applications of these metals have been hampered by two considerations: availability and price. Zirconium will shortly be produced at a rate sufficient to supply industrial needs, and titanium has been available to industry during the past two years. And it is expected that increased production of these metals during the next few years will result in significant price decreases.

Twelve to thirteen thousand tons of titanium were available in 1956 and present construction schedules indicate that the figure will rise substantially in 1957. U.S.I.'s new plant alone will add 5,000 tons to the annual production capacity by the end of the year. Zirconium will be on the market in quantity by mid-1957. When its new plant at Ashtabula, Ohio gets under way, U.S.I. will be able to supply 500,000 pounds or more per year to commercial users in addition to its Atomic Energy Commission commitments of 1,000,000 pounds per year.

New Metals Economical

Chemical process equipment can now be fabricated from titanium for a little over twice the price of stainless steel, and it is expected that in the future titanium equipment will be only 50-75% higher than stainless. Commercial grade zirconium equipment will probably be priced only 75-100% higher than stainless when volume production is reached.

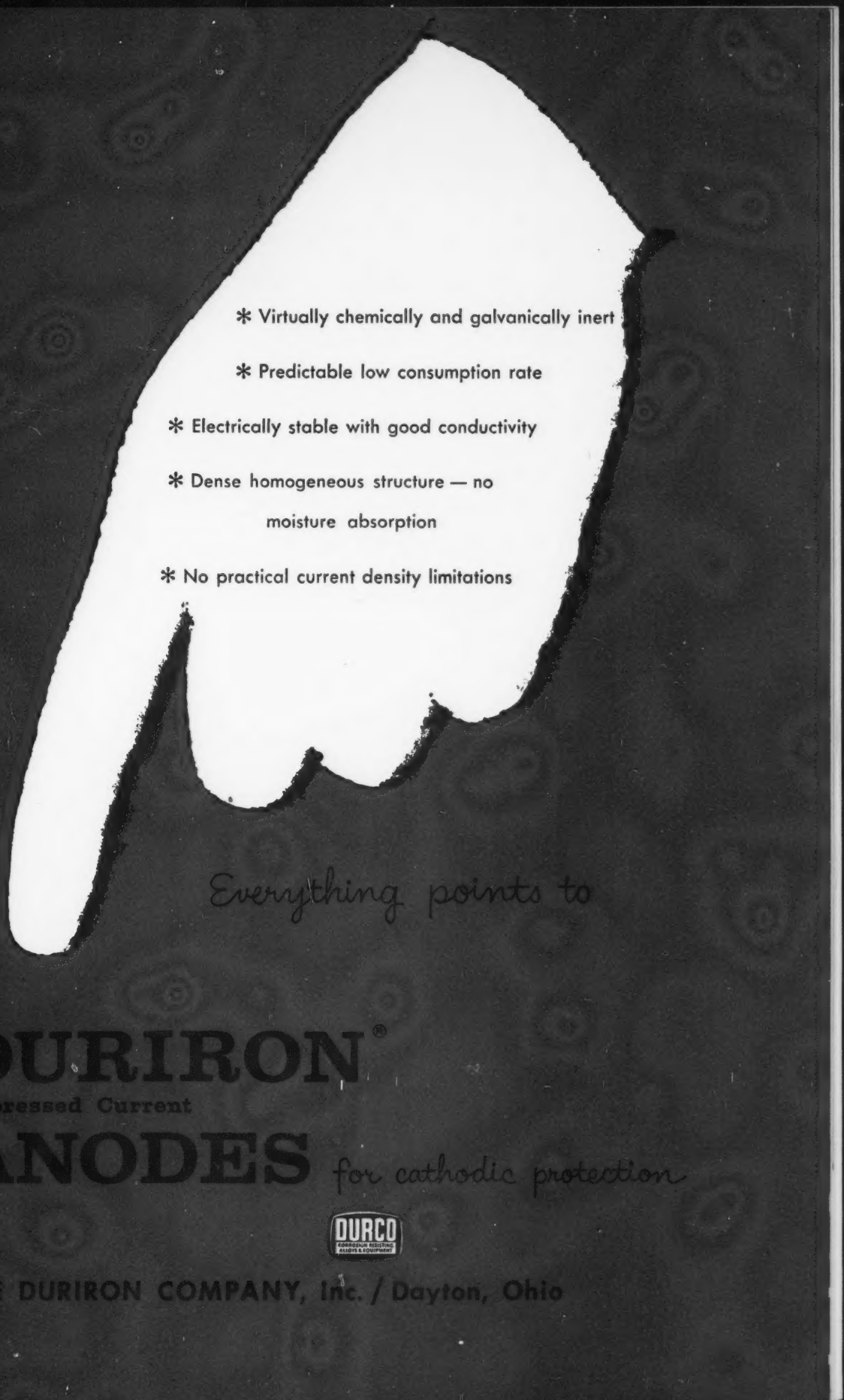
Typical Corrosion Resistances* of Zirconium and Titanium

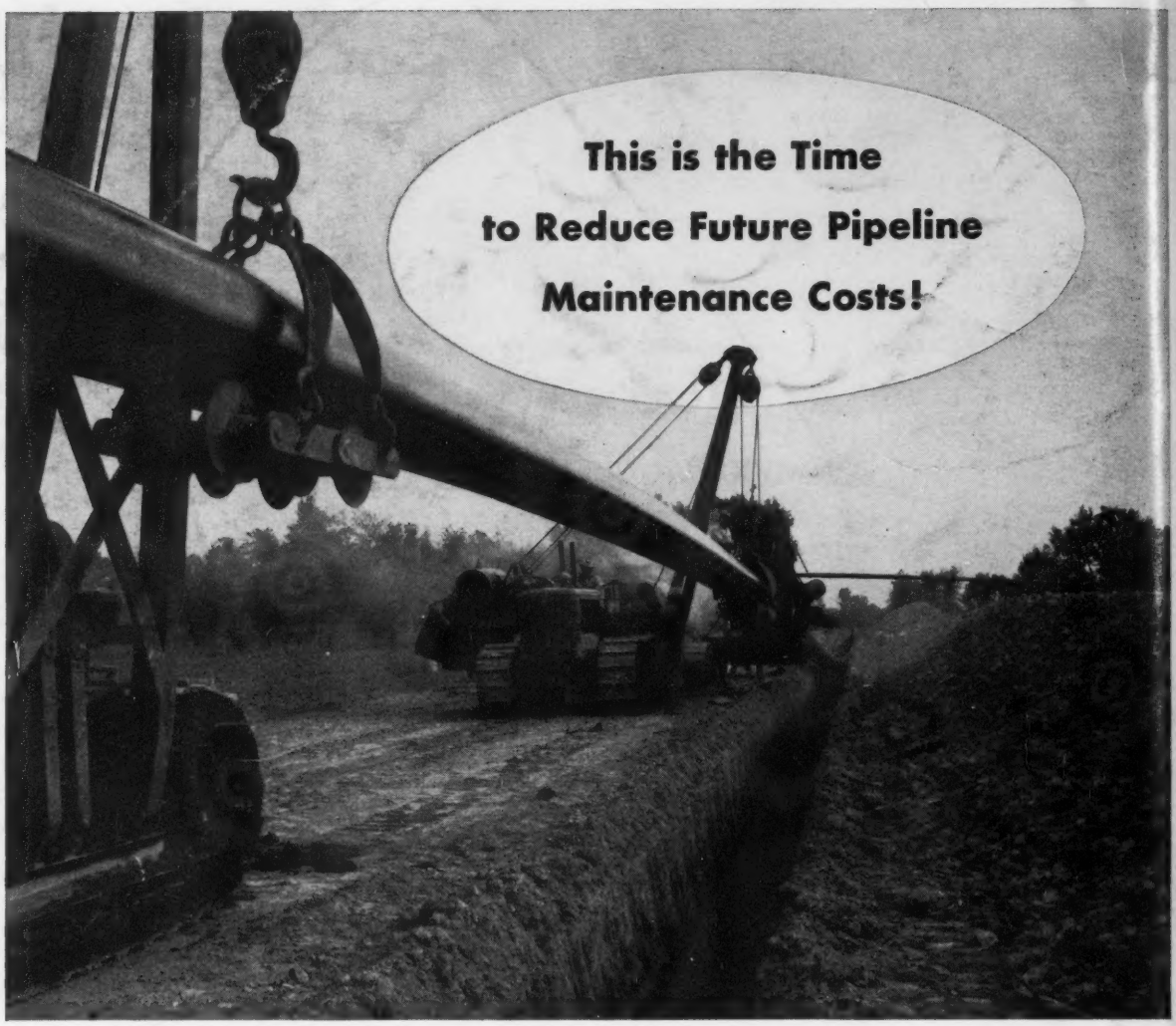
Corrosive Media	Metal Resistance	
	Zirconium	Titanium
Sulfuric Acid	excellent to good below 80%	good below 5%
Nitric Acid	excellent	excellent
Hydrochloric Acid	excellent	good below 10%
Phosphoric Acid	excellent to fair below 85%	poor
Chromic Acid	excellent	excellent to good
Aqua Regia	poor	excellent
Wet Chlorine Gas	poor	excellent
Chlorine Water	excellent	excellent
Sodium Hydroxide	good below 90%	good below 50%
Ferric Chloride	poor	excellent
Calcium Chloride	excellent	excellent
Cupric Chloride	poor	excellent
Sodium Chloride	excellent	excellent
Ammonium Chloride	excellent	excellent
Aluminum Chloride	excellent	excellent to fair

*Above data do not cover all conditions because of space limitations. Literature references may be obtained by writing the Editor, U.S.I. Chemical News, 99 Park Ave., N. Y. 16, N. Y.

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